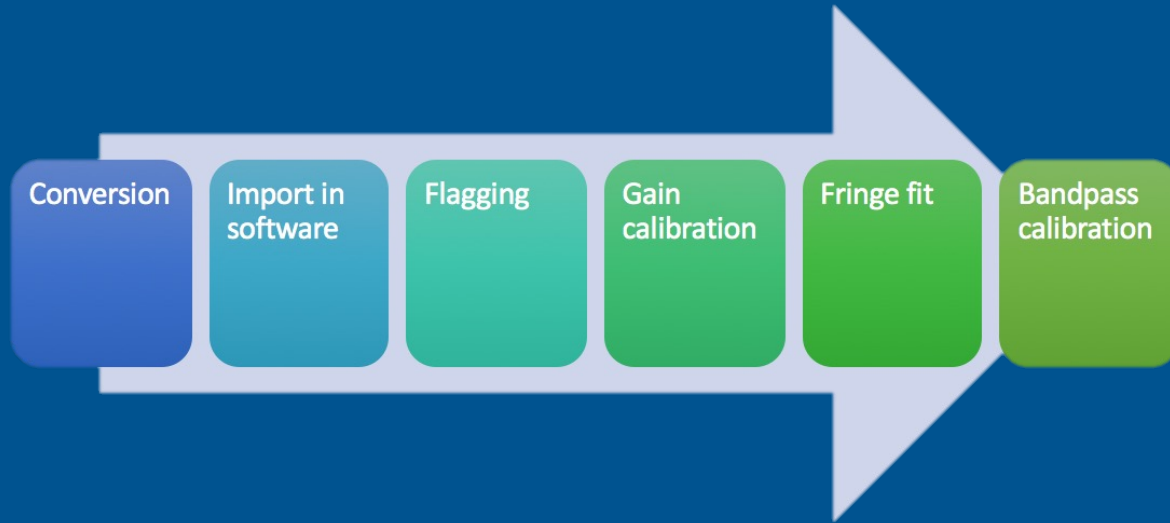


# VLBI continuum calibration

Getting your hands dirty

# All calibration steps (tomorrow!)

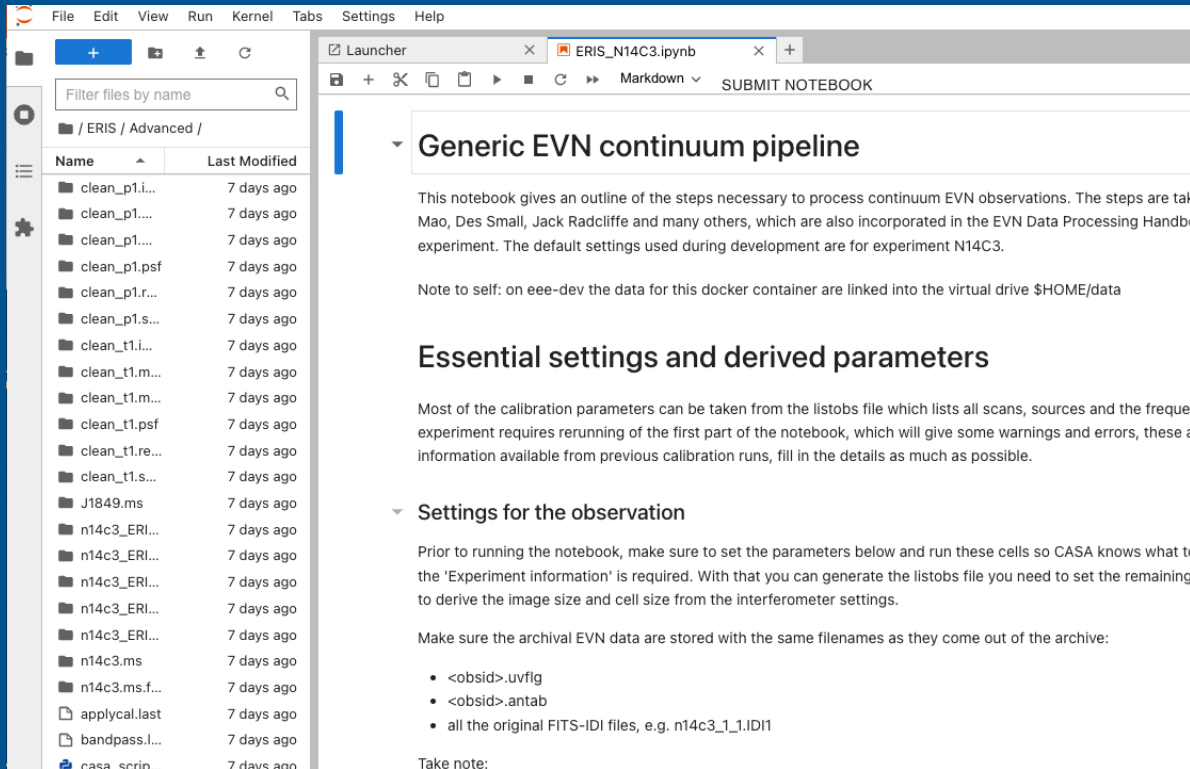


Online materials:

[Gitea repository](#)

[DARA EVN continuum tutorial](#)

# Jupyter-CASA interface



The screenshot displays the Jupyter-CASA interface. On the left is a file browser pane showing a directory structure under '/ERIS / Advanced /'. It lists various files including 'clean\_p1.i...', 'clean\_p1...', 'clean\_p1...', 'clean\_p1.psf', 'clean\_p1.r...', 'clean\_p1.s...', 'clean\_t1.i...', 'clean\_t1.m...', 'clean\_t1.m...', 'clean\_t1.psf', 'clean\_t1.re...', 'clean\_t1.s...', 'J1849.ms', 'n14c3\_ERI...', 'n14c3\_ERI...', 'n14c3\_ERI...', 'n14c3\_ERI...', 'n14c3\_ERI...', 'n14c3.ms', 'n14c3.ms.f...', 'applycal.last', 'bandpass.i...', and 'casa\_scrip...'. All files are marked as '7 days ago'.

The main pane on the right shows a Jupyter notebook titled 'ERIS\_N14C3.ipynb'. The notebook has a 'Launcher' tab and a 'SUBMIT NOTEBOOK' button. The content of the notebook is as follows:

## Generic EVN continuum pipeline

This notebook gives an outline of the steps necessary to process continuum EVN observations. The steps are taken from the work of Mao, Des Small, Jack Radcliffe and many others, which are also incorporated in the EVN Data Processing Handbook. The default settings used during development are for experiment N14C3.

Note to self: on eee-dev the data for this docker container are linked into the virtual drive \$HOME/data

## Essential settings and derived parameters

Most of the calibration parameters can be taken from the listobs file which lists all scans, sources and the frequencies. If the experiment requires rerunning of the first part of the notebook, which will give some warnings and errors, these can be ignored. Information available from previous calibration runs, fill in the details as much as possible.

## Settings for the observation

Prior to running the notebook, make sure to set the parameters below and run these cells so CASA knows what to do. The 'Experiment information' is required. With that you can generate the listobs file you need to set the remaining parameters. To derive the image size and cell size from the interferometer settings.

Make sure the archival EVN data are stored with the same filenames as they come out of the archive:

- <obsid>.uvflag
- <obsid>.antab
- all the original FITS-IDI files, e.g. n14c3\_1.IDI1

Take note:

# This tutorial

1. Inspect a VLBI dataset (listobs, plotms)
2. Find a good scan
3. Fringefit
4. If time: inspect & apply the calibration tables



# This tutorial

## Preparations:

- Have the materials downloaded from [Gitea](#)
- Make sure you type `git pull` before starting
- Go into the Plenary folder
- Launch CASA

You can execute every command in a WHITE BOX  
(beware of plotms!)

# 1. Inspecting your data

## CASA task listobs

```
# listobs -- List the summary of a data set in the logger or in
vis              = ''                # Name of input visibility file
selectdata       = True              # Data selection parameters
  spw             = ''                # Selection based on spectral window
  field           = ''                # Selection based on field name
  antenna         = ''                # Selection based on antenna
  uvrange         = ''                # Selection based on uvrange
  timerange       = ''                # Selection based on timerange
  correlation      = ''                # Selection based on correlation
  scan            = ''                # Selection based on scan number
  intent          = ''                # Selection based on intent
  feed            = ''                # Selection based on feed
  array           = ''                # Selection based on array name
  observation      = ''                # Selection based on observation
verbose          = True              # Controls level of information
listfile         = ''                # Name of disk file to write
listunfl         = False             # List unflagged rows only
cachesize        = 50.0              # EXPERIMENTAL. Maximum cache size
```

```
listobs(vis='n14c3_TY_GC_flags.ms/')
```

```
=====
MeasurementSet Name:  /Users/bemmel/Science/EVN_CASA/ERIS/Plenary/n14c3_TY_GC_flags.ms      MS Version 2
=====
Observer: N14C3      Project: N14C3
Observation: EVN
Data records: 1846080      Total elapsed time = 10800 seconds
Observed from 22-Oct-2014/12:00:00.0 to 22-Oct-2014/15:00:00.0 (UTC)

ObservationID = 0      ArrayID = 0
Date      Timerange (UTC)      Scan      FldId      FieldName      nRows      SpwIds      Average Interval(s)      ScanIntent
22-Oct-2014/12:00:00.0 - 12:04:00.0      1      1      3C345      52800      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:06:00.0 - 12:10:00.0      2      1      3C345      63360      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:12:00.0 - 12:13:00.0      3      1      3C345      15840      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:13:40.0 - 12:14:40.0      4      1      3C345      15840      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:15:20.0 - 12:16:20.0      5      0      J1640+3946      15840      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:17:00.0 - 12:18:00.0      6      1      3C345      13200      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:18:40.0 - 12:19:40.0      7      0      J1640+3946      13200      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:20:20.0 - 12:21:20.0      8      1      3C345      15840      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:22:00.0 - 12:23:00.0      9      0      J1640+3946      15840      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:23:40.0 - 12:24:40.0      10      1      3C345      13200      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:25:20.0 - 12:26:20.0      11      0      J1640+3946      13200      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:27:00.0 - 12:28:00.0      12      1      3C345      15840      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:28:40.0 - 12:29:40.0      13      0      J1640+3946      15840      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:30:20.0 - 12:31:20.0      14      1      3C345      13200      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:32:00.0 - 12:33:00.0      15      0      J1640+3946      13200      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:33:40.0 - 12:34:40.0      16      1      3C345      15840      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:35:20.0 - 12:36:20.0      17      0      J1640+3946      15840      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:37:00.0 - 12:38:00.0      18      1      3C345      13200      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
12:38:40.0 - 12:39:40.0      19      0      J1640+3946      13200      [0,1,2,3,4,5,6,7]      [2, 2, 2, 2, 2, 2, 2, 2]
```

Fields: 5

ID	Code	Name	RA	Decl	Epoch	nRows
0		J1640+3946	16:40:29.632770	+39.46.46.02836	J2000	254400
1		3C345	16:42:58.809965	+39.48.36.99402	J2000	383520
2		J1849+3024	18:49:20.103406	+30.24.14.23712	J2000	276480
3		1848+283	18:50:27.589825	+28.25.13.15523	J2000	388800
4		2023+336	20:25:10.842114	+33.43.00.21435	J2000	542880

Spectral Windows: (8 unique spectral windows and 1 unique polarization setups)

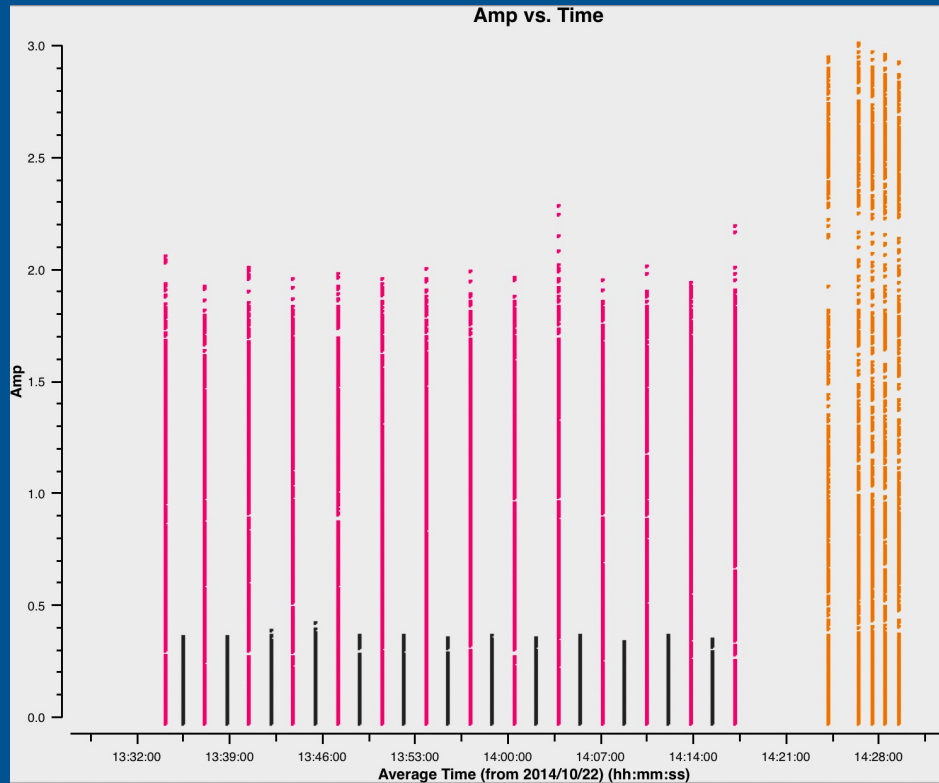
SpwID	Name	#Chans	Frame	Ch0(MHz)	ChanWid(kHz)	TotBW(kHz)	CtrFreq(MHz)	Corrs			
0	none	32	GEO	4926.990	500.000	16000.0	4934.7400	RR	RL	LR	LL
1	none	32	GEO	4942.490	500.000	16000.0	4950.2400	RR	RL	LR	LL
2	none	32	GEO	4958.990	500.000	16000.0	4966.7400	RR	RL	LR	LL
3	none	32	GEO	4974.490	500.000	16000.0	4982.2400	RR	RL	LR	LL
4	none	32	GEO	4990.990	500.000	16000.0	4998.7400	RR	RL	LR	LL
5	none	32	GEO	5006.490	500.000	16000.0	5014.2400	RR	RL	LR	LL
6	none	32	GEO	5022.990	500.000	16000.0	5030.7400	RR	RL	LR	LL
7	none	32	GEO	5038.490	500.000	16000.0	5046.2400	RR	RL	LR	LL

Antennas: 12:

ID	Name	Station	Diam.	Long.	Lat.
0	EF	EF	0.0 m	+006.53.01.0	+50.20.09.1
1	WB	WB	0.0 m	+006.38.00.0	+52.43.48.0
2	JB	JB	0.0 m	-002.18.30.9	+53.03.06.6
3	ON	ON	0.0 m	+011.55.04.0	+57.13.05.3
4	NT	NT	0.0 m	+014.59.20.6	+36.41.29.4
5	TR	TR	0.0 m	+018.33.50.6	+52.54.37.8
6	SV	SV	0.0 m	+029.46.55.0	+60.22.02.0
7	ZC	ZC	0.0 m	+041.33.54.6	+43.35.44.2
8	BD	BD	0.0 m	+102.14.02.1	+51.34.59.0
9	SH	SH	0.0 m	+121.11.58.8	+30.55.45.2
10	HH	HH	0.0 m	+027.41.07.4	-25.44.20.1
11	YS	YS	0.0 m	-003.05.12.7	+40.20.05.0

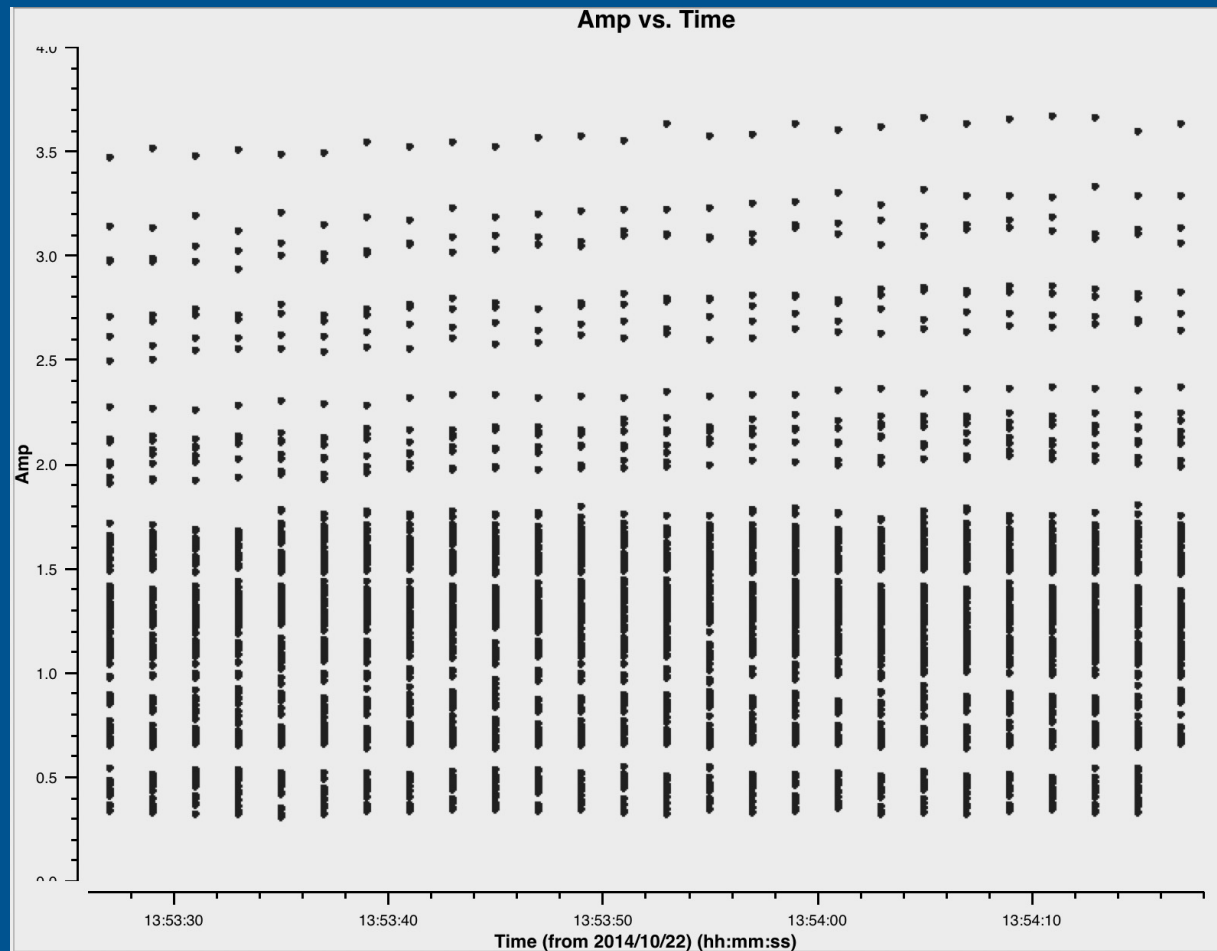


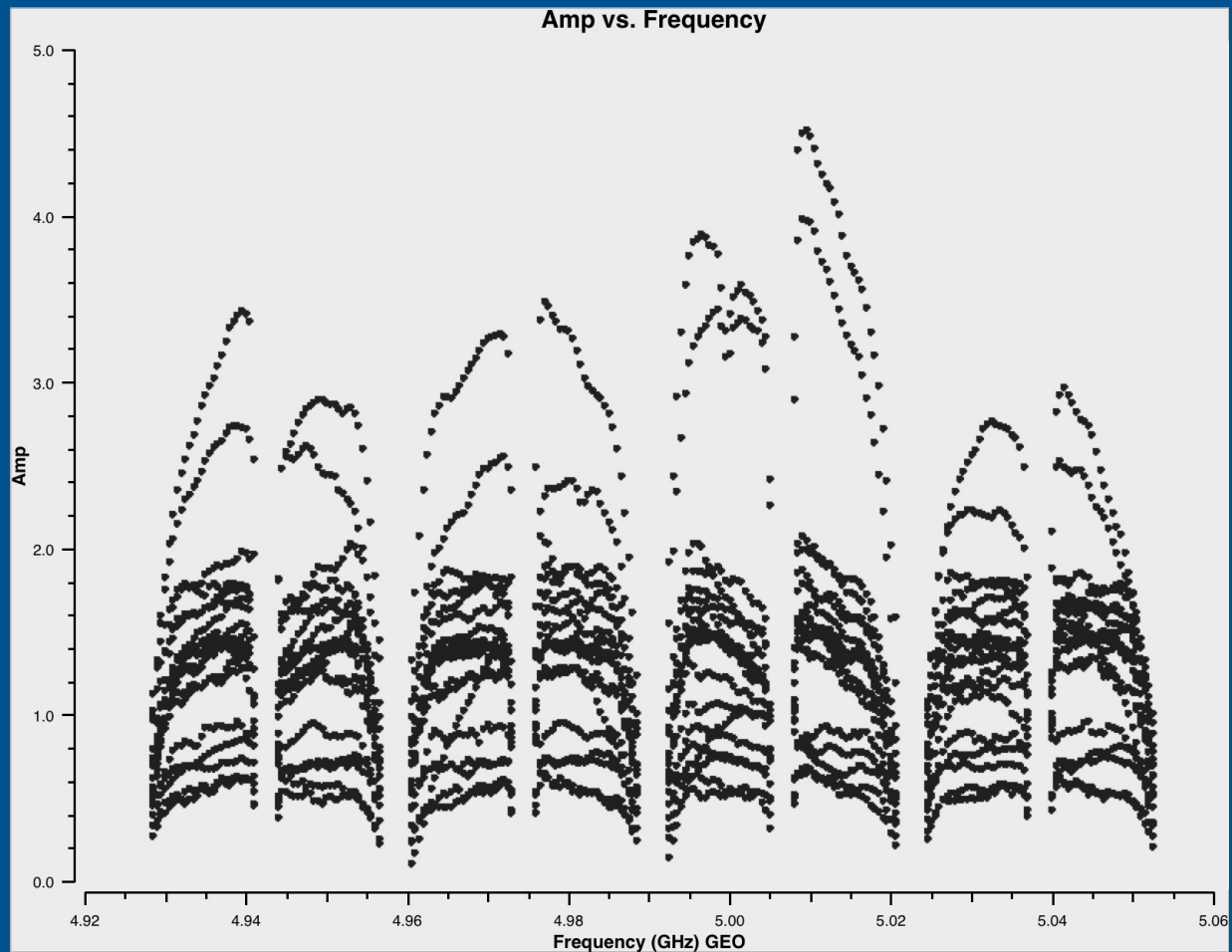
```
plotms(vis='n14c3_TY_GC_flags.ms/', <...>, ...)
```



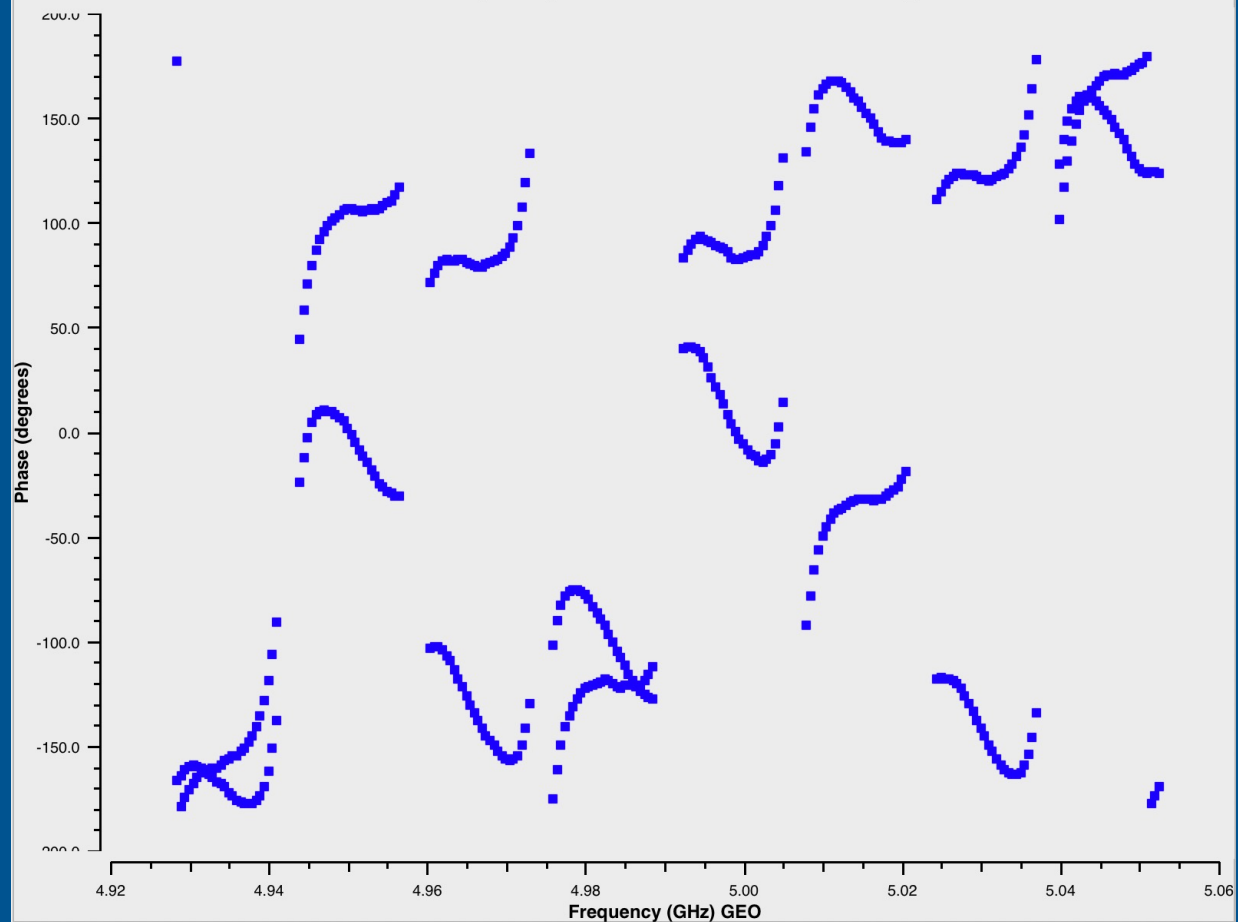
## 2. Selecting a calibration scan

- Bright source
- Middle of the observation
- Single scan for the instrumental delay correction
- Verify:
  - All antennas present
  - Stable phases in time/freq
  - No weird stuff in amplitudes

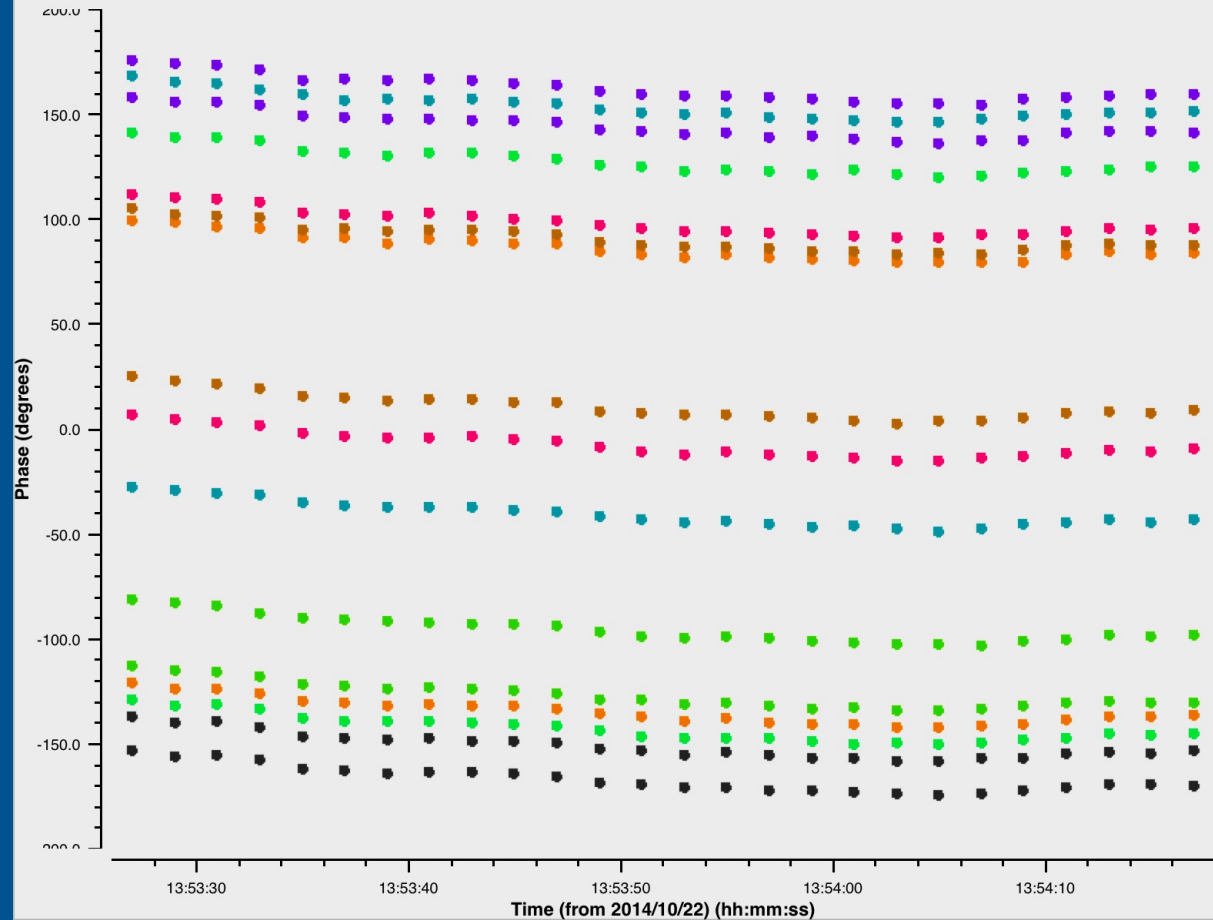




Phase vs. Frequency Baseline: EF@EF & WB@WB\_266520m



Phase vs. Time Baseline: EF@EF & WB@WB\_266520m



### 3. Fringe fitting

CASA task: `fringefit`

- Requires:
  - Single scan on bright target
  - Select middle timerange of the scan, ~1-2 minutes
  - Select a reference antenna
  - Always set `parang = True` for VLBI
  - Instrumental delay: `zerorates=true`

```

# fringeft -- Fringe fit delay and rates
vis              = ''          # Name of input visibility file
caltable         = ''          # Name of output gain calibration table
field            = ''          # Select field using field id
spw              = ''          # Select spectral window/channel
intent           = ''          # Select observing intent
selectdata      = True        # Other data selection parameters
    timerange     = ''          # Select data based on time range
    antenna       = ''          # Select data based on antenna
    scan          = ''          # Scan number range
    observation    = ''          # Select by observation ID(s)
    msselect       = ''          # Optional complex data selection
solint           = 'inf'       # Solution interval: egs. 'inf'
combine          = ''          # Data axes which to combine
refant           = ''          # Reference antenna name(s)
minsnr           = 3.0         # Reject solutions below this SNR
zerorates        = False       # Zero delay-rates in solution
globalsolve      = True        # Refine estimates of delay rates
niter            = 100         # Maximum number of iterations
delaywindow      = []          # Constrain FFT delay search range
ratewindow       = []          # Constrain FFT rate search range
append           = False       # Append solutions to the existing
corrdepflags     = False       # Respect correlation-dependent
docallib         = False       # Use callib or traditional
    gaintable     = []          # Gain calibration table(s)
    gainfield     = []          # Select a subset of calibration
    interp        = []          # Temporal interpolation for
    spwmap        = []          # Spectral window mappings to
paramactive      = []          # Control which parameters are
parang           = False       # Apply parallactic angle correction

```



# Selecting a reference antenna

- For EVN: use Effelsberg (EF)
  - Biggest dish
  - Well behaved meta-data
  - Central in the array
- The parameter accepts a string, e.g.  
`refant = "EF,TR,ON"`
- If not sure: use CASA task `plotants`

# On-the-fly calibration

- `docallib = False`
- `gaintable=[ 'n14c3_ERIS.tsys', 'n14c3_ERIS.gcal' ]`
- `interp=[ 'nearest,nearest', 'nearest' ]`

# All fringe fit parameters

```
fringe fit(vis='n14c3_TY_GC_flags.ms/',  
          caltable='n14c3_ERIS.sbd',  
          timerange='13:53:20.0~13:54:20.0',  
          solint='inf',  
          refant='EF',  
          minsnr=50,  
          zerorates=True,  
          corrdepflags=True,  
          gaintable=['n14c3_ERIS.gcal', n14c3_ERIS.tsys'],  
          interp=['nearest', 'nearest', 'nearest'],  
          parang=True  
)
```

## 4. Inspect the results

2022-09-19	13:23:28	WARN	...ingefit:::	MS	obs=0,fld=0,spw=0,ant=12	cannot be calibrated
2022-09-19	13:23:28	WARN	...ingefit:::	MS	obs=0,fld=0,spw=1,ant=12	cannot be calibrated
2022-09-19	13:23:28	WARN	...ingefit:::	MS	obs=0,fld=0,spw=2,ant=12	cannot be calibrated
2022-09-19	13:23:28	WARN	...ingefit:::	MS	obs=0,fld=0,spw=3,ant=12	cannot be calibrated
2022-09-19	13:23:28	WARN	...ingefit:::	MS	obs=0,fld=0,spw=4,ant=12	cannot be calibrated
2022-09-19	13:23:29	WARN	...ingefit:::	MS	obs=0,fld=0,spw=5,ant=12	cannot be calibrated
2022-09-19	13:23:29	WARN	...ingefit:::	MS	obs=0,fld=0,spw=6,ant=12	cannot be calibrated
2022-09-19	13:23:29	WARN	...ingefit:::	MS	obs=0,fld=0,spw=7,ant=12	cannot be calibrated

This is normal, don't worry!

## 4. Inspect the results

```
Using reference antenna 0
sPok [8, 13]
Antenna 1 correlation 0 has (FFT) SNR of 1609.38.
Antenna 2 correlation 0 has (FFT) SNR of 1926.22.
Antenna 3 correlation 0 has (FFT) SNR of 5533.
Antenna 4 correlation 0 has (FFT) SNR of 3867.23.
Antenna 5 correlation 0 has (FFT) SNR of 5968.37.
Antenna 6 correlation 0 has (FFT) SNR of 0 below threshold (50).
Antenna 7 correlation 0 has (FFT) SNR of 7999.78.
Antenna 8 correlation 0 has (FFT) SNR of 6248.67.
Antenna 9 correlation 0 has (FFT) SNR of 885.085.
Antenna 10 correlation 0 has (FFT) SNR of 0 below threshold (50).
Antenna 11 correlation 0 has (FFT) SNR of 10894.2.
Antenna 1 correlation 1 has (FFT) SNR of 1596.69.
Antenna 2 correlation 1 has (FFT) SNR of 2517.05.
Antenna 3 correlation 1 has (FFT) SNR of 4479.48.
Antenna 4 correlation 1 has (FFT) SNR of 4135.53.
Antenna 5 correlation 1 has (FFT) SNR of 17669.6.
Antenna 6 correlation 1 has (FFT) SNR of 9734.02.
Antenna 7 correlation 1 has (FFT) SNR of 6020.06.
Antenna 8 correlation 1 has (FFT) SNR of 9241.53.
Antenna 9 correlation 1 has (FFT) SNR of 901.532.
Antenna 10 correlation 1 has (FFT) SNR of 1171.34.
Antenna 11 correlation 1 has (FFT) SNR of 8385.43.
Starting least squares optimization.
Least squares complete for correlation 0 after 3 iterations.
Least squares complete for correlation 1 after 3 iterations.
Zeroing delay rates in calibration table.
```

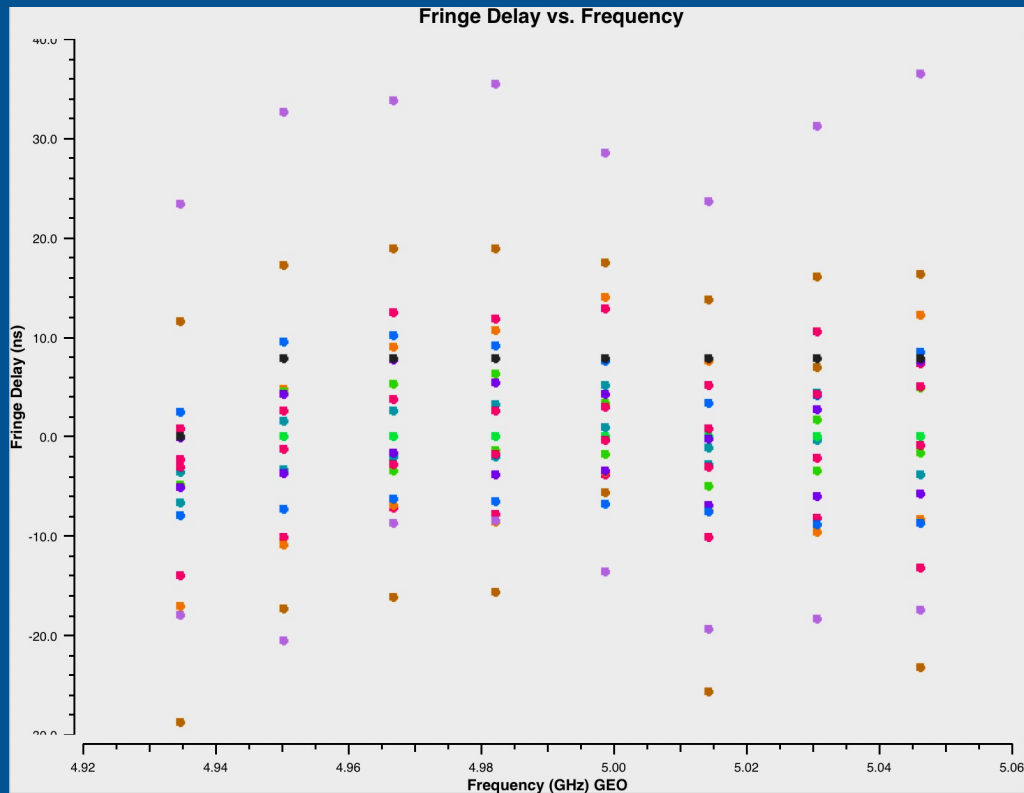
## 4. Inspect the results

```
Finished solving.  
Calibration solve statistics per spw: (expected/attempted/succeeded):  
  Spw 0: 1/1/1  
  Spw 1: 1/1/1  
  Spw 2: 1/1/1  
  Spw 3: 1/1/1  
  Spw 4: 1/1/1  
  Spw 5: 1/1/1  
  Spw 6: 1/1/1  
  Spw 7: 1/1/1  
Task fringeFit complete. Start time: 2022-09-19 15:23:25.938173 End time: 2022-09-19 15:23:25.938173  
##### End Task: fringeFit #####
```

# Plot the calibration table

CASA task `plotms`

Instead of MS, use  
calibration table as `vis`



# Plot the calibration table

```
plotms(vis='n14c3_ERIS.sbd',  
       axis='freq',  
       yaxis='delay',  
       coloraxis='antenna1')
```



## 5. Apply the calibration

CASA task `applycal`

Creates CORRECTED\_DATA column in your MS

- Add all available calibration tables
- Set the interpolation
- Set `parang=True`
- To clean-up a calibration: task `clearcal`

## 5. Apply the calibration

```
applycal(vis='n14c3_TY_GC_flags.ms/',  
gainable=['n14c3_ERIS.gcal', 'n14c3_ERIS.tsys',  
          'n14c3_ERIS.sbd'],  
interp=['nearest', 'nearest,nearest', 'nearest'],  
parang=True,  
flagbackup=False  
)
```

# Plot the calibrated phases

```
plotms(vis='n14c3_TY_GC_flags.ms',  
       axis='freq',  
       yaxis='phase',  
       ydatacolumn='corrected',  
       timerange='13:53:20~13:54:20',  
       antenna='EF',  
       coloraxis='baseline',  
       correlation='LL',  
       averagedata=True,  
       avgtime='120'  
)
```