VLA Data Reduction: *Standard Calibration*

Amy Kimball (NRAO)

Using these slides as a reference

This presentation is based on a 12.5-GB (raw) data set that can be downloaded from the new NRAO Data Archive:

data.nrao.edu

ON YOUR OWN

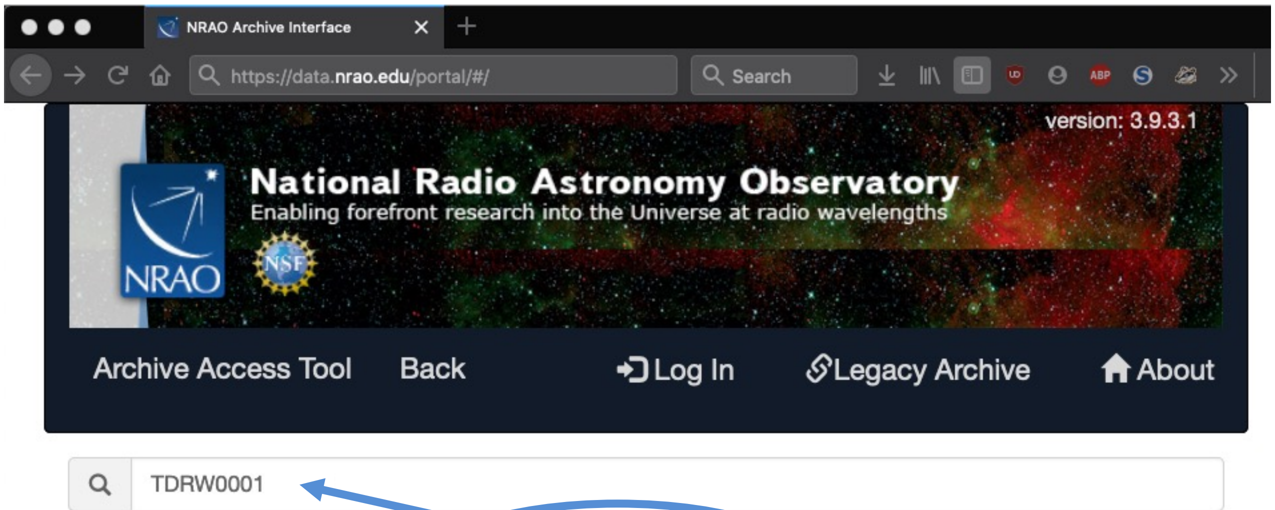
```
# When you see text like this and the sidebar to the left:
CASA commands and input parameters for
CASA tasks will appear like this
```

Accessing data used for this presentation

ON YOUR OWN

This presentation is based on a 12.5-GB (raw) data set that can be downloaded from the new NRAO Data Archive:

data.nrao.edu



Search for: **TDRW0001**

Download ~12.5 GB data set: (TDRW0001.sb35624494.eb35628826.58395.23719237269)

Accessing data used for this presentation

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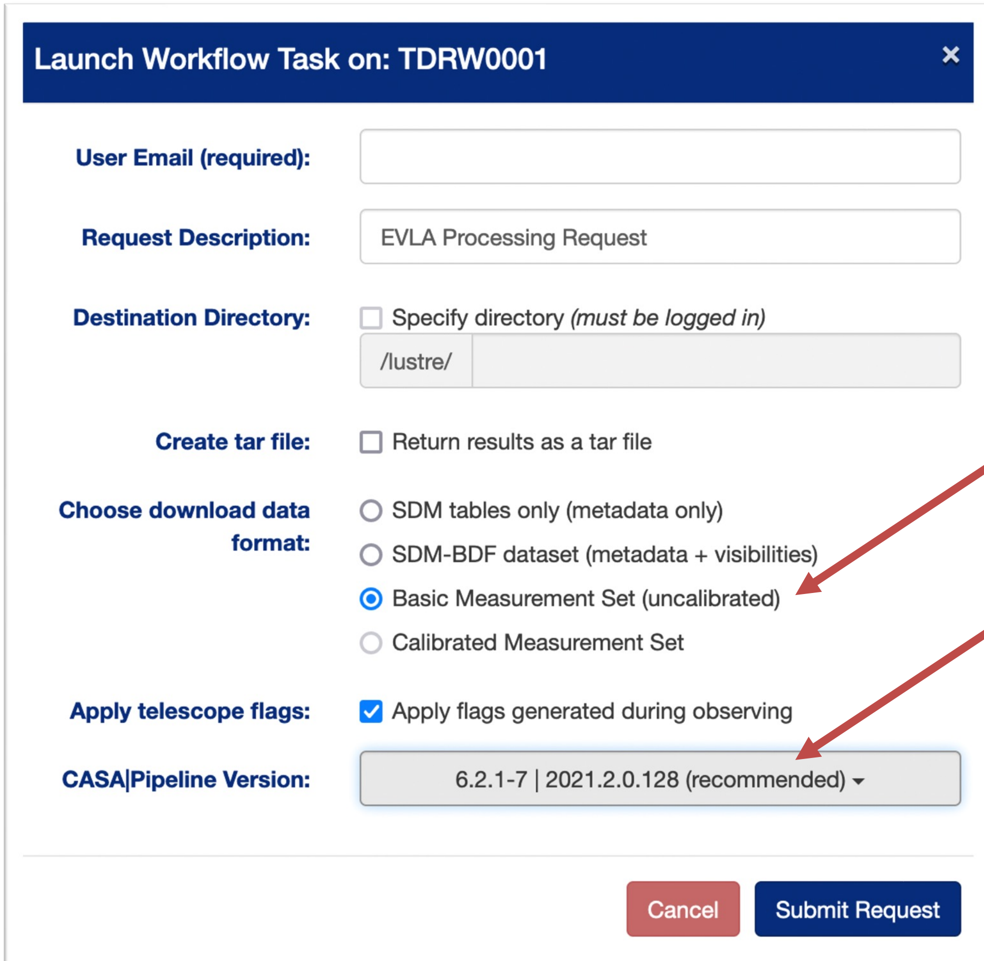

IF you are downloading a measurement set (MS), you must select the CASA version that will be used to convert the raw data (SDM-BDF) to MS.

CASA versions are usually (but not always) backwards compatible. CASA version shown here is the version used for this presentation: 6.2.1-7 | 2021.2.0.128.

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Accessing data used for this presentation

Steps to prepare the data set for this presentation:

- Download and unzip/untar Measurement Set (MS):

Name	Last modified	Size
Parent Directory		-
PPR.xml	2022-10-03 10:29	5.4K
TDRW0001.sb35624494.eb35628826.58395.23719237269.ms.tgz	2022-10-03 10:51	10G
casa_commands.log	2022-10-03 10:42	2.0K
casa_pipescript.py	2022-10-03 10:42	793
pipeline_aquareport.xml	2022-10-03 10:51	1.2K
unknown.auxproducts.tgz	2022-10-03 10:51	612
unknown.pipeline_manifest.xml	2022-10-03 10:51	795
unknown.pprequest.xml	2022-10-03 10:42	5.4K
weblog.tgz	2022-10-03 10:42	1.8M

- Use mstransform to split out:
  - spw = '6~8'
  - scan = '5~11'
  - datacolumn = 'data'
  - keepflags = False
  - hanning = True
- Set outputvis to something simple: "my_data.ms"

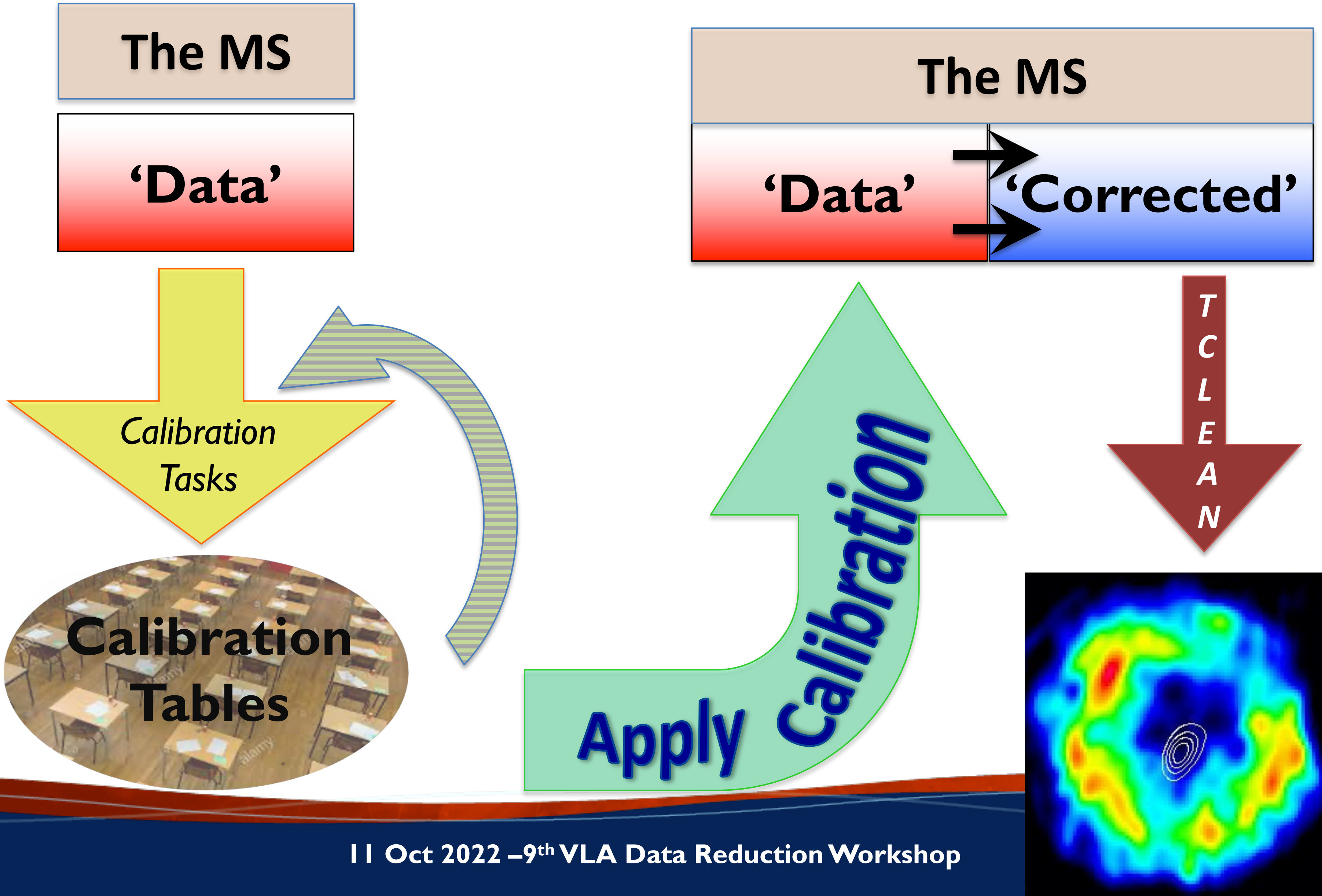
Final data set size is ~1.2 GB.

The measurement set (MS) structure

'Data' column	'Corrected' Column	'Model' Column (optional)
Raw Data	Calibrated Data	FT of source model

- A raw MS starts with only the 'Data' column.
- The other two columns can be created by various means.
- With creation of the other two columns → MS *triples* in size.
- The 'Model' Column is optional.
  - If not created → MS *doubles* in size.
  - "Virtual" models can be "attached" to the MS, FT-ed and used when needed (replacing the need for the 'Model' column).

Calibration & Imaging Flow



Calibration

- Correcting antenna positions
- Gain Curves (high-freq)
- Opacity (high-) and Ionospheric (low-freq) corrections
- *Switched power* **
- Re-quantizer gain calibration (mostly 3-bit data)

} *A priori* calibration

- Setting the flux density scale
- Delay calibration
- Pre-bandpass phase-only calibration (high-freq)
- Bandpass calibration
- Complex gain calibration
- (Polarization Calibration)
- Setting the flux density scales of the complex gain calibrators

gencal: *CASA task for various types of corrections*

```
'amp' = amplitude correction
'ph'  = phase correction
'sbd' = single-band delay
'mbd' = multi-band delay
```
'antpos' = ITRF antenna position corrections

'antposvla' = for pre-upgrade VLA (*see documentation*)

'swpow' = EVLA switched-power gains **

'rq' = EVLA requantizer gains

'swp/rq' = EVLA switched power gains/req. gains

'opac' = Tropospheric opacity

'gc' = VLA gain curve (zenith-angle-dependent gain)

'eff' = VLA antenna efficiency (sqrt(K/Jy))

'gceff' = VLA gain curve and efficiency

'tecim' = Total electron content for ionospheric corrections

Antenna Positions: *gencal*

- Correct baselines after antenna moves
  - operator's log reports recent antenna moves
- Use the task *gencal* to produce a calibration table that will include the antenna position corrections
  - (check whether table was needed/created)

- Baseline correction related information is at: http://www.vla.nrao.edu/astro/archive/baselines/

Antenna position corrections

- CASA task *gencal*

```
# CASA parameters for gencal
vis = 'my_data.ms'
caltable = 'antpos.cal'
caltype = 'antpos'
```

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Antenna position corrections (if any) are reported in the casalogger:

offsets for antenna ea02 : -0.00060 0.00220 -0.00130
offsets for antenna ea04 : 0.00150 0.00190 -0.00150
offsets for antenna ea06 : 0.00120 0.00190 -0.00140
offsets for antenna ea13 : 0.00110 0.00120 -0.00140
offsets for antenna ea16 : 0.00110 0.00120 -0.00180
offsets for antenna ea20 : -0.00190 0.00110 -0.00130
offsets for antenna ea25 : -0.00340 0.00190 -0.00280

Gain Curves: *gencal*

- Large antennas have a forward gain that changes with elevation.
- Gain curves describe how each antenna behaves as a function of elevation, for each receiver band.
- The polynomial coefficients for the VLA are available directly from the CASA data repository.
- Important for ***higher frequencies*** (>15 GHz).
- The VLA pipeline *always* performs this step.
- In *gencal*, set:

```
caltype  = 'gc'
caltable = 'gaincurve.cal'
```

Opacity Corrections: *plotweather*

- Atmospheric optical depth, important for *high frequencies* (>15 GHz)
- CASA task *plotweather* uses weather statistics and/or seasonal models to estimate opacities and make weather plots

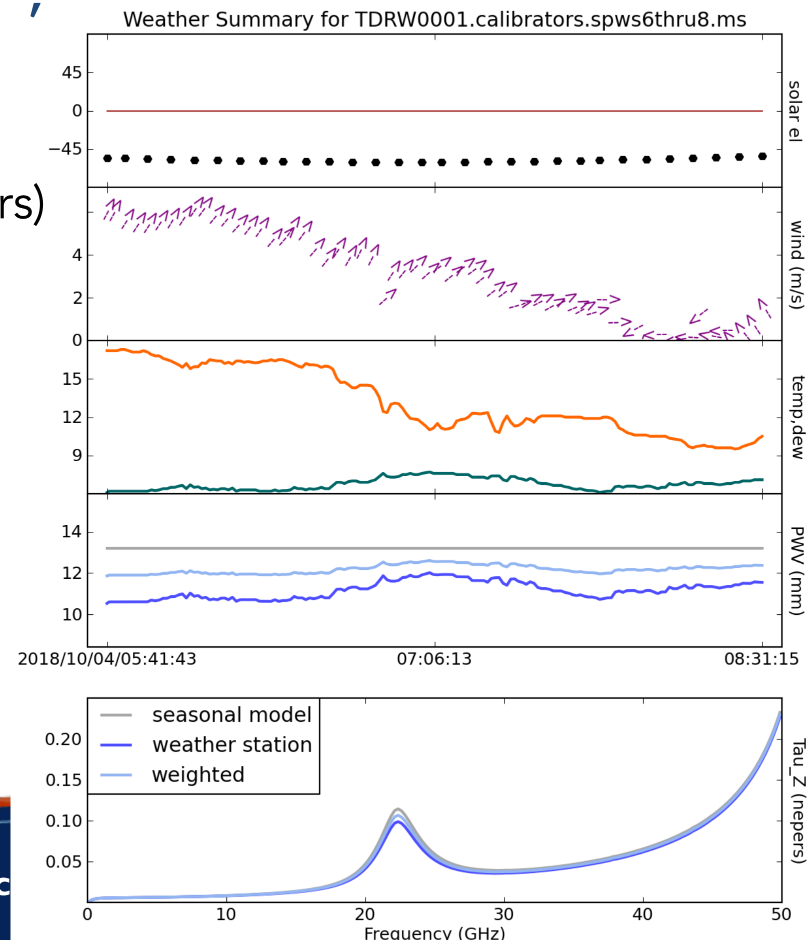
```
tau_val = plotweather( vis='<ms name>',
doPlot=True, plotName='weather.png' )
```

- Gives one value per spw:

SPW	Frequency (GHz)	Zenith opacity (nepers)
0	3.000	0.006
1	3.128	0.006
2	3.256	0.006

- Apply to data with *gencal* task:

```
caltype   = 'opac'
caltable  = 'opacity.cal'
parameter =  tau_val
spw = '0~2'  # (match to tau_val spws)
```



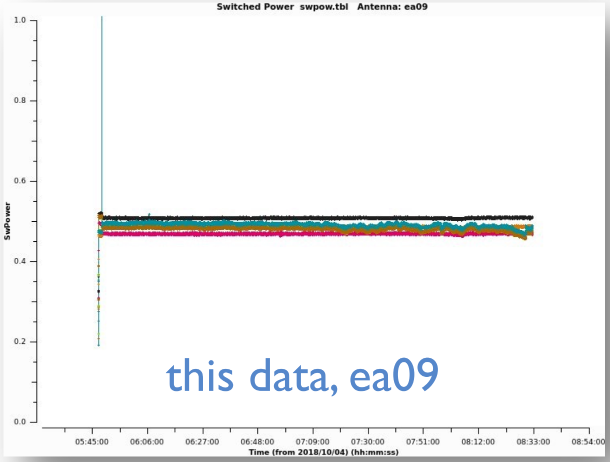
“Sys” Power / Switched-power gain

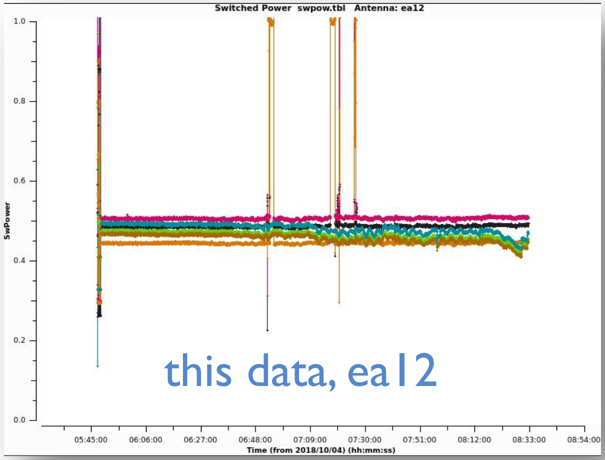
- For the VLA, the total power received is continuously monitored during an observation, using a calibration signal of known power switched in/out at 10 Hz.
- The values stored in the syspower table ***can*** be used to calibrate amplitude gains.
- We ***do not*** recommend blind application of syspower (e.g., in gencal with caltype=‘swpow’); this is not a commissioned mode.
- What is now available *in the pipeline* is application of a polynomial fit to the syspower pattern to correct for *gain compression.*

Gain compression*: when a strong signal (e.g. RFI) increases the gain of the amplifier into a non-linear regime.*

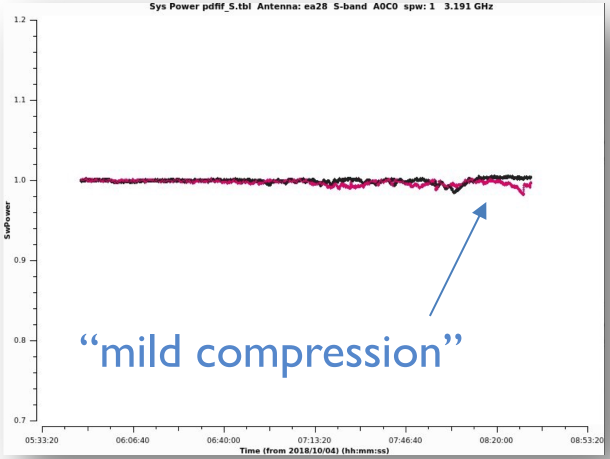
Sys-power examples (pipeline plots)

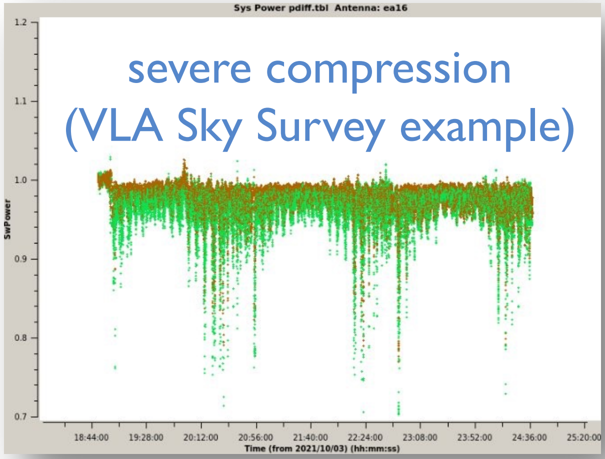
Switched power table values:





"Pdiff"-- on/off power difference:





The Ionosphere: *Total Electron Content (TEC)*

Free electrons in the atmosphere cause a dispersive delay (phase errors). Effect goes as ν^{-2} but depends on ever-changing atmosphere:

- introduces Faraday rotation
- changes measured source position

TEC corrections are:

- Important for VLA low frequencies *(P, L, S bands; C and X if active Sun)*
- Important for large arrays (*baselines* $\gtrsim$ *5 km; VLA's A and B config*)
- Important for polarimetry
- **Still under commissioning**

By default the VLA pipeline does NOT perform TEC corrections.

(in pipelines 6.4 and onward: TEC corrections are *optional*

Ionosphere correction (*Total Electron Content*)

- CASA "recipe" and CASA task *gencal*

`tec_maps` module retrieves TEC info from a NASA database.*

```
# In CASA
# import the TEC image     (in CASA 5, import from "recipes")
from casatasks.private import tec_maps
tec_image, tec_rms_image, tec_graph = tec_maps.create(
    vis='my_data.ms', doplot=True)

# gencal parameters
caltype = 'tecim'
caltable = 'tecim.cal'
infile = tec_image
```

* https://cddis.nasa.gov/Data_and_Derived_Products/GNSS/atmospheric_products.html

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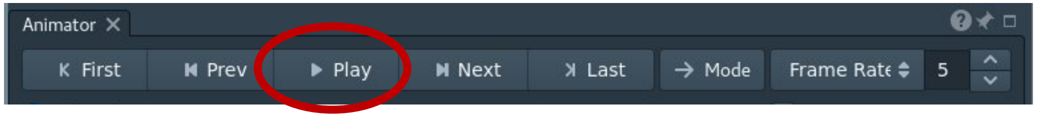
TEC image and rms image for this dataset

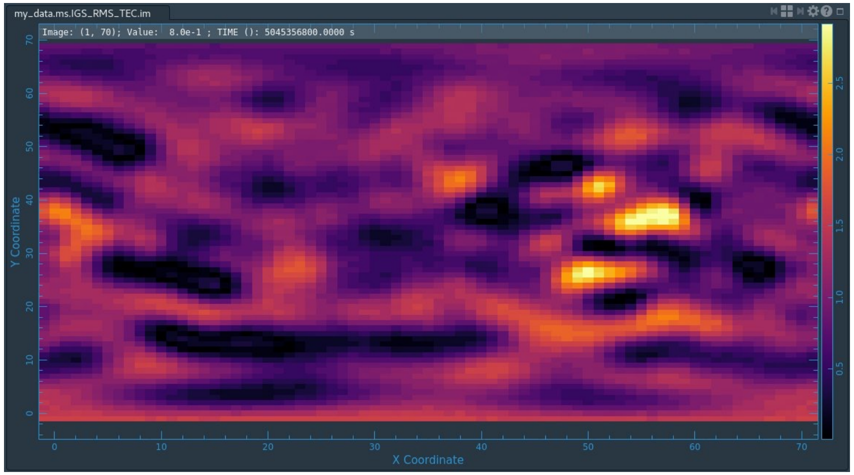
```
# open carta in a terminal, paste the reported URL into a local browser tab
carta --no_browser
```

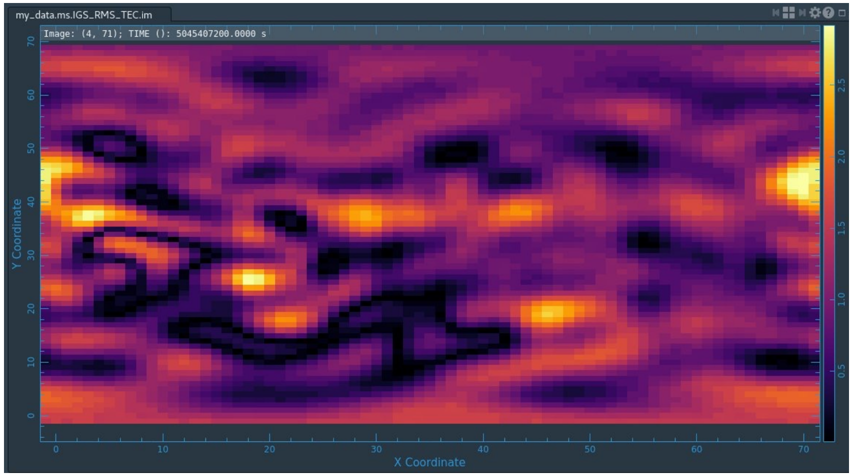
TEC is time dependent:

open animator widget

press “Play”







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Requantizer gains: *gencal*

- Optimizes the digital power within each spectral window.
- Required for *3-bit data*. (This example data set is 8-bit data.)
- Strongly recommended for *all P-band data*.
- In *gencal*, set:

```
caltype  = 'rq'
caltable = 'requant_gains.cal'
```

Calibration

- ✓ Correcting antenna positions
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- ✓ Re-quantizer gain calibration (mostly 3-bit data)

} *A priori* calibration

- Setting the flux density scale
- Delay calibration
- Pre-bandpass phase-only calibration (high-freq)
- Bandpass calibration
- Complex gain calibration
- (Polarization Calibration)
- Setting the flux density scales of the complex gain calibrators

Calibration: setting the flux density scale

- CASA task *setjy* calculates the absolute flux density as a function of frequency (and time):
  - for standard flux density calibrators (e.g., Perley-Butler 2017)
  - for Solar System objects (e.g., Butler-JPL-Horizons 2012)
- If provided, attaches a model record to the MS

```
field              =  '<fluxcal field name or #>'
standard           = 'Perley-Butler 2017'
      model        = '<source/band model name>'
      listmodels   =   True or False
usescratch         =      False
```

Identifying available flux density models

- CASA task *setjy*

```
# CASA parameters for setjy
standard = 'Perley-Butler 2017'  # default; other models available
listmodels = True
```

`listmodels`

- For `True`, instead of calculating flux density, CASA will list the available primary calibrator models (3C138, 3C147, 3C286, 3C48; P, L, S, C, X, U, K, A, Q bands).

P-band models have another standard available:

`standard = 'Scaife-Heald 2012':`

3C48, 3C147, 3C196, 3C286, 3C295, 3C380

- 3C123 and 3C138 available for P-band only with "Perley-Butler 2017"

ON YOUR OWN

Setting the flux density scale

- CASA task *setjy*

In CASA
```
result = setjy(vis='my_data.ms', field='0',
               model='3C48_S.im')
```

output of `setjy` captured in variable "result":

{'0': {'0': {'fluxd': array([8.44827557, 0.   , 0.   , 0.   ])},
  '1': {'fluxd': array([8.13441944, 0.   , 0.   , 0.   ])},
  '2': {'fluxd': array([7.84281111, 0.   , 0.   , 0.   ])},
  'fieldName': '0137+331=3C48'},
 'format': "{field Id: {spw Id: {fluxd: [I,Q,U,V] in Jy}, 'fieldName':field name }}"}

CASA reports in casalog:

Selected 54756 out of 97929 rows.
0137+331=3C48 (fld ind 0) spw 0 [I=8.4483, Q=0, U=0, V=0] Jy @ 3e+09Hz, (Perley-Butler 2017)
0137+331=3C48 (fld ind 0) spw 1 [I=8.1344, Q=0, U=0, V=0] Jy @ 3.128e+09Hz, (Perley-Butler 2017)
0137+331=3C48 (fld ind 0) spw 2 [I=7.8428, Q=0, U=0, V=0] Jy @ 3.256e+09Hz, (Perley-Butler 2017)

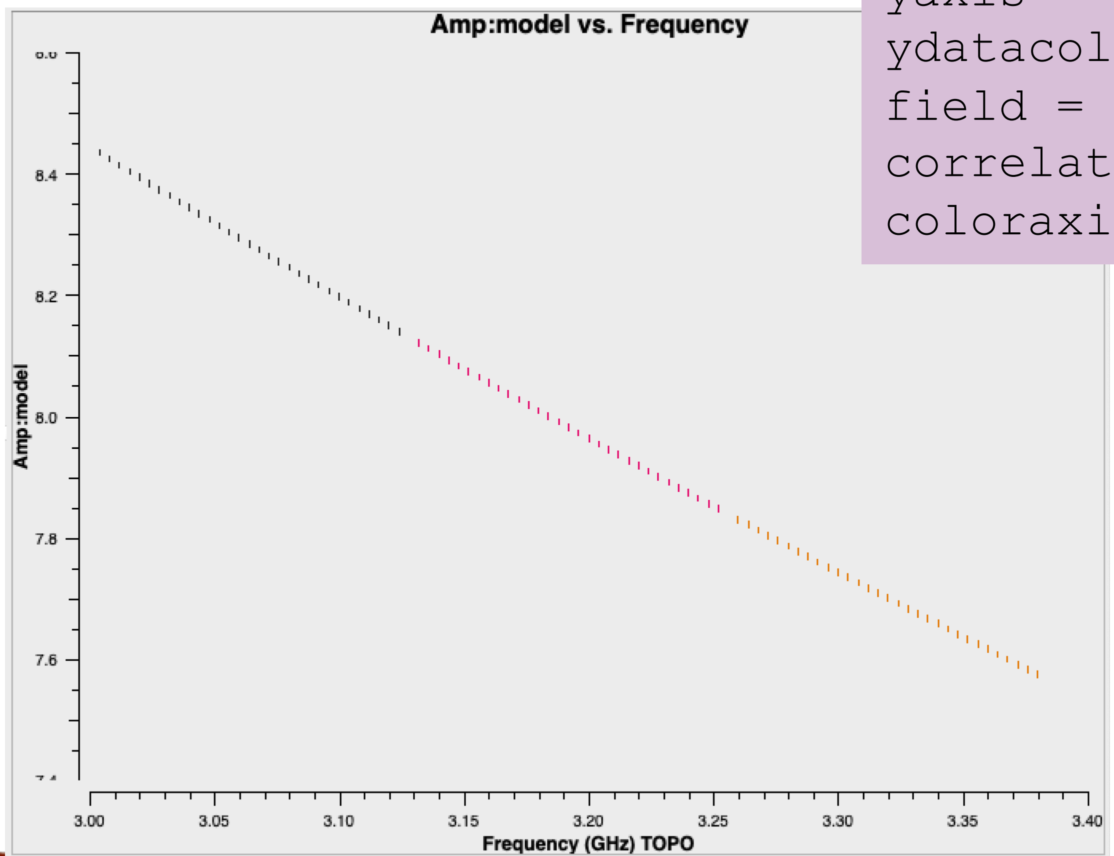
ON YOUR OWN

Examine flux density scale calibrator model

ON YOUR OWN

- CASA task *plotms*

```
# CASA parameters for plotms
vis = 'my_data.ms'
xaxis = 'freq'
yaxis = 'amp'
ydatacolumn = 'model'
field = '0'
correlation = 'RR,LL'
coloraxis = 'spw'
```



Setting the flux density scale manually: *setjy*

- User can choose to provide flux density values rather than letting the task calculate them (manual mode)

```
standard        =    'manual'
    fluxdensity     = [8.446, 0, 0, 0]     # Stokes I, Q, U,V in Jy
    spix            = [-0.925,0]           # [alpha, curvature]
    reffreq         = '3 GHz'
```

Can also use *setjy* to provide:

`polindex`: coefficients for frequency dependence of linear polarization fraction
`polangle`: coefficients for frequency dependence of polarization angle
`rotmeas`: rotation measure (rad/m^2)

* Polarization discussed tomorrow in Frank Schinzel's talk

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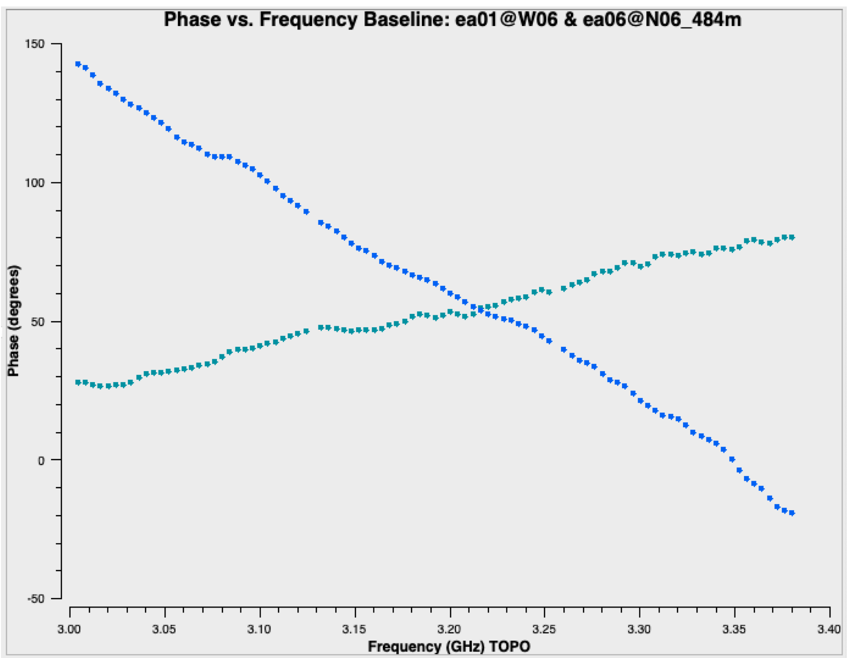
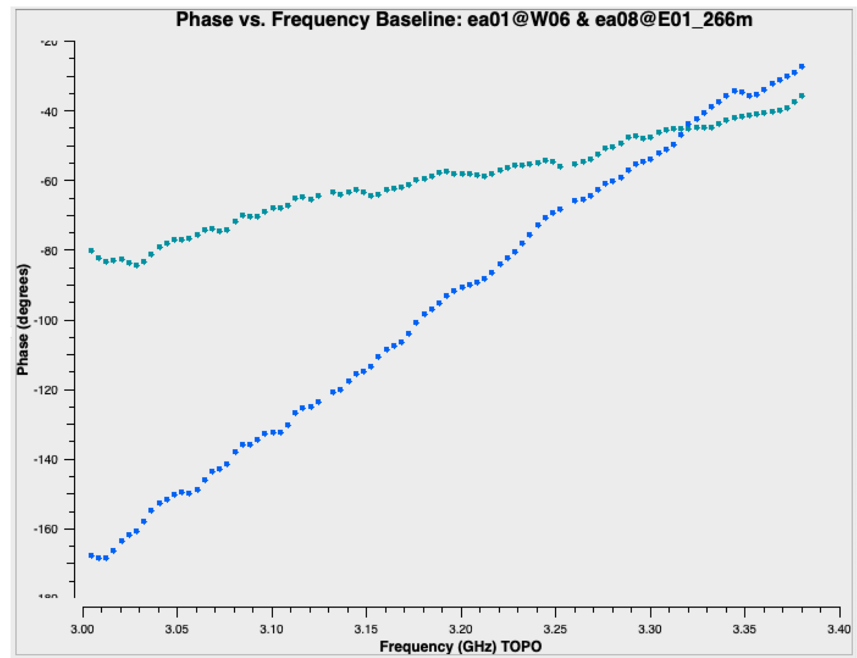
Antenna-based residual delays

- Seen in UV data as linear phase-ramp vs frequency:
  - varying with baseline, correlation (RR, LL), baseband





Calibrating antenna-based delays

- CASA task *gaincal*

```
# CASA parameters for gaincal
vis = 'my_data.ms'
caltable = 'delays.cal'
solint = 'inf'          # 'inf' = infinite: combines all data within a scan
refant = 'ea10'
scan = '5'   # can use one scan, or use all with e.g.: field = '0'  combine = 'scan'
gaintype = 'K'
gaintable = ['antpos.cal', 'tecim.cal']
```

Use a strong (high signal-to-noise) source--- e.g. flux/bandpass calibrator.

`gaintype = 'K'`: solve for the residual delay solutions

`gaintable = [list]`: include all previous calibration tables

Warning! Data with "failed" solutions will be flagged later, during *applycal* stage

ON YOUR OWN

Calibration

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- ✓ Re-quantizer gain calibration (mostly 3-bit data)

} *A priori* calibration

- ✓ Setting the flux density scale
- ✓ Delay calibration
- Pre-bandpass phase-only calibration (high-freq)
- Bandpass calibration

} Bandpass

- Complex gain calibration
- (Polarization Calibration)
- Setting the flux density scales of the complex gain calibrators

Before Bandpass Calibration

- Bandpass calibration is needed not just for spectral-line observations, but also for continuum.
- Before calibrating the bandpass, may choose to do a phase-only calibration on the bandpass calibrator (to be applied *only* when calibrating the bandpass).
  - Prevents de-correlation when vector averaging.
  - Critical for *high frequency* observations.
  - Can also be used in low frequency observations.

Bandpass Calibration

Needed for continuum observations too!

Uncalibrated bandpass!

Plotms settings:

- bandpass calibrator
- amp vs freq
- parallel-hands (RR, LL)
- avg in time
- iterate over baseline
- color by spw

Note: sensitivity falls off in ~3 channels at each edge of a spw. (Effect of digital filtering.)

Pre-bandpass phase-only calibration

CASA task *gaincal*

```
caltable = '<output cal table>'
solint = 'int'          # 'int' = integration
calmode = 'p'           # phase-only
spw = '0~2:13~18'       # a few RFI-free channels
gaintype = 'G'          # standard gaincal:  one solution per pol, spw
gaintable = ['antpos.cal', 'tecim.cal', 'delays.cal']
```

Use *short solution interval* and a *few channels* per spw (RFI-free) to avoid de-correlation.

The resulting caltable must *only* be used for calibrating the bandpass.

Bandpass calibration

- CASA task *bandpass*

```
# CASA parameters for bandpass
vis = 'my_data.ms'
caltable = 'bandpass.cal'
field = '0'
solint = 'inf'
refant = 'ea10'
gaintable = ['antpos.cal', 'tecim.cal', 'delays.cal']
```

("pre-bandpass phase-only" caltable would also go in this list)

- `solint` can provide an interval in time and/or frequency

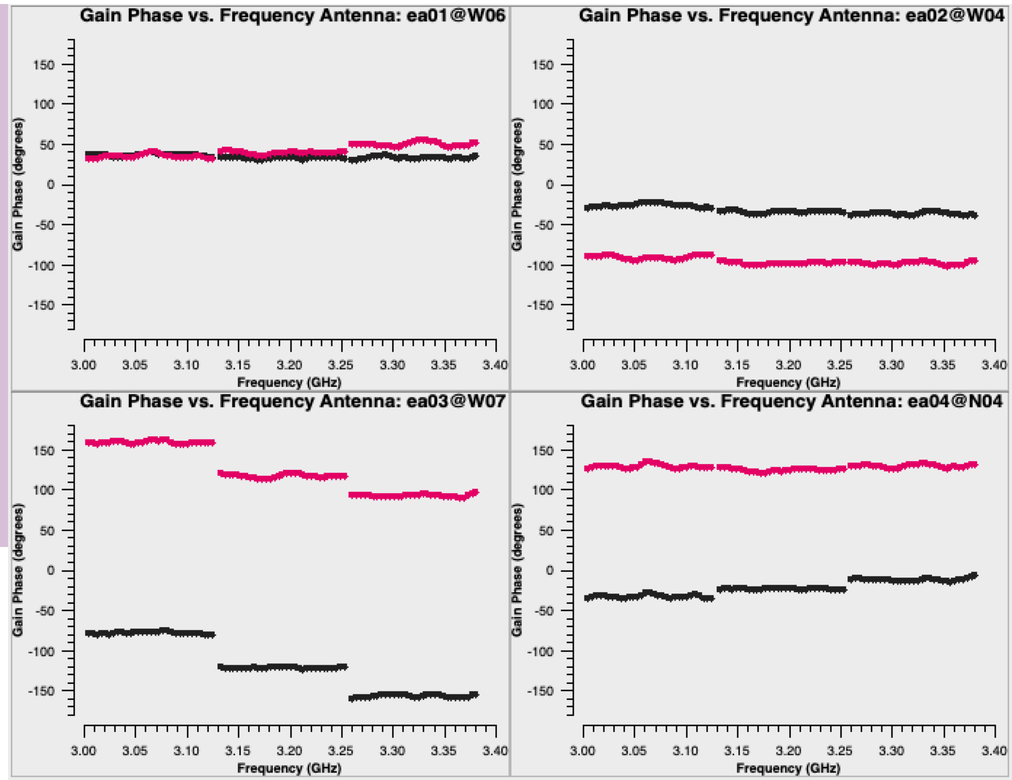
If bandpass cal ≠ flux cal, must account for spectral index/curvature.
Topical CASAguide: *"Correcting for a Spectral Index in Bandpass Calibration"*:
https://casaguides.nrao.edu/ → VLA

ON YOUR OWN

Examine bandpass calibration *phase* solutions

- CASA task *plotms*
  - Parameter "`vis`" can be a caltable
  - `coloraxis` = `'corr'` → actually polarization

```
# CASA parameters for plotms
vis = 'bandpass.cal'
gridrows = 2
gridcols = 2
xaxis = 'freq'
yaxis = 'phase'
iteraxis = 'antenna'
coloraxis = 'corr'
plotrange = [-1,-1,-180,180]
```

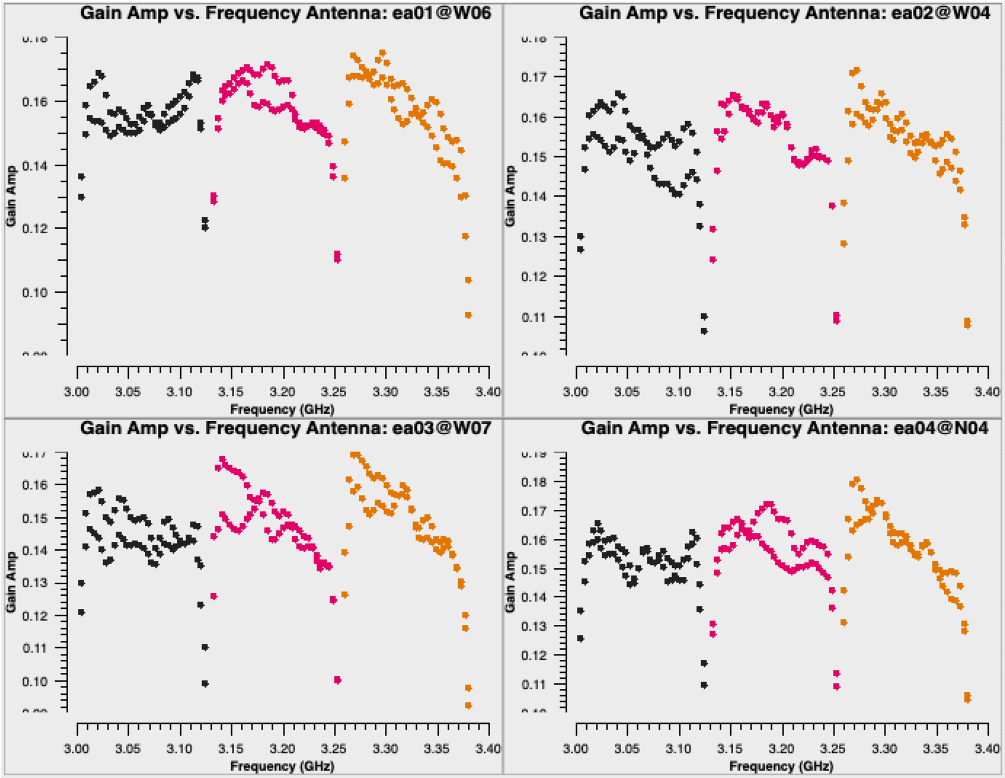


Move forward with ▶ and see that reference antenna (ea10) has phases = 0°.

Examine bandpass calibration *amp* solutions

- CASA task *plotms*

```
# CASA parameters for plotms
vis = 'bandpass.cal'
gridrows = 2
gridcols = 2
xaxis = 'freq'
yaxis = 'amp'
iteraxis = 'antenna'
coloraxis = 'spw'
plotrange = []
```

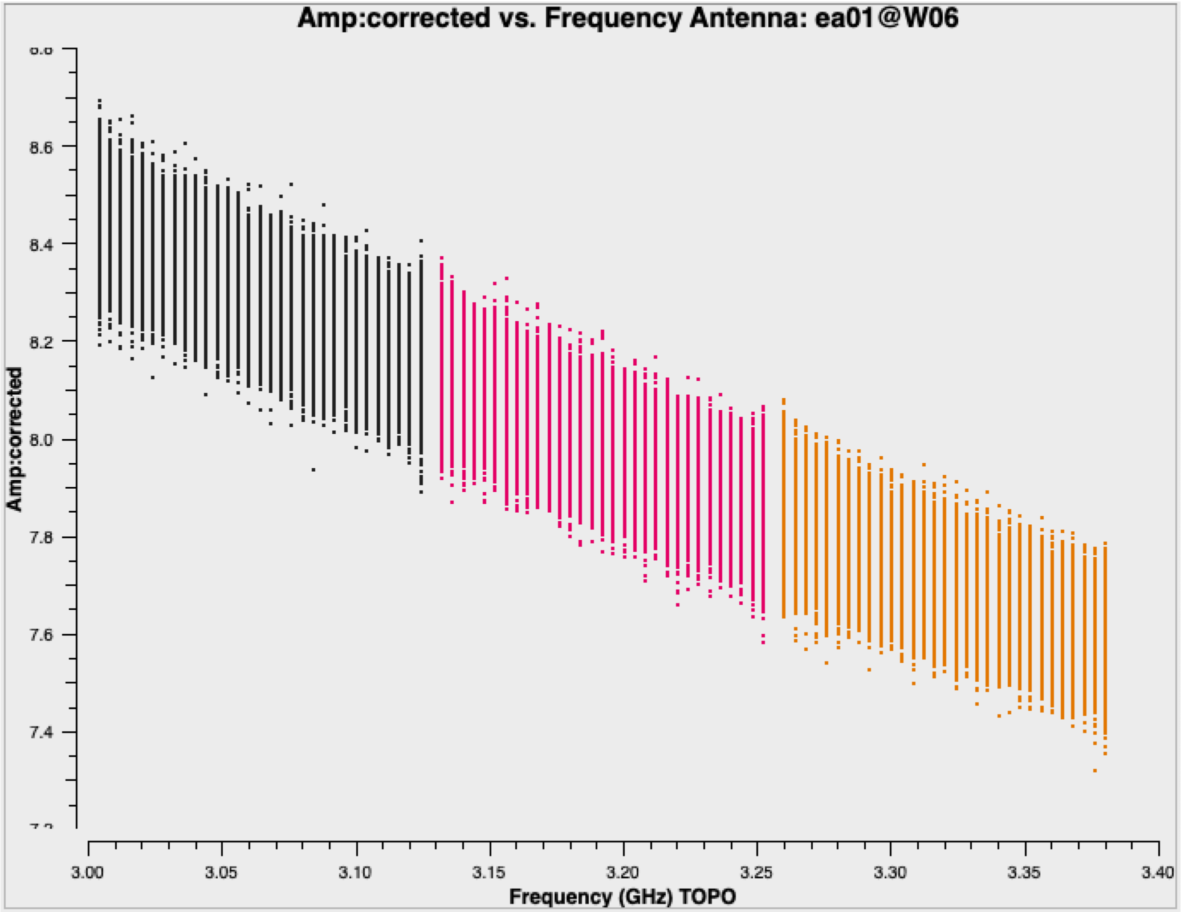


Note similarity to bandpass amp shapes (slide 29). These are the values that will be *applied* to the data in order to "correct" the bandpasses.

ON YOUR OWN

Bandpass-corrected 3C48 data

(CASA tasks *applycal* and *plotms)*



Calibration

- ✓ Correcting antenna positions
- ✓ Gain Curves (high-freq)
- ✓ Opacity (high-) and Ionospheric (low-freq) corrections
- ✓ *Switched power* **
- ✓ Re-quantizer gain calibration (mostly 3-bit data)

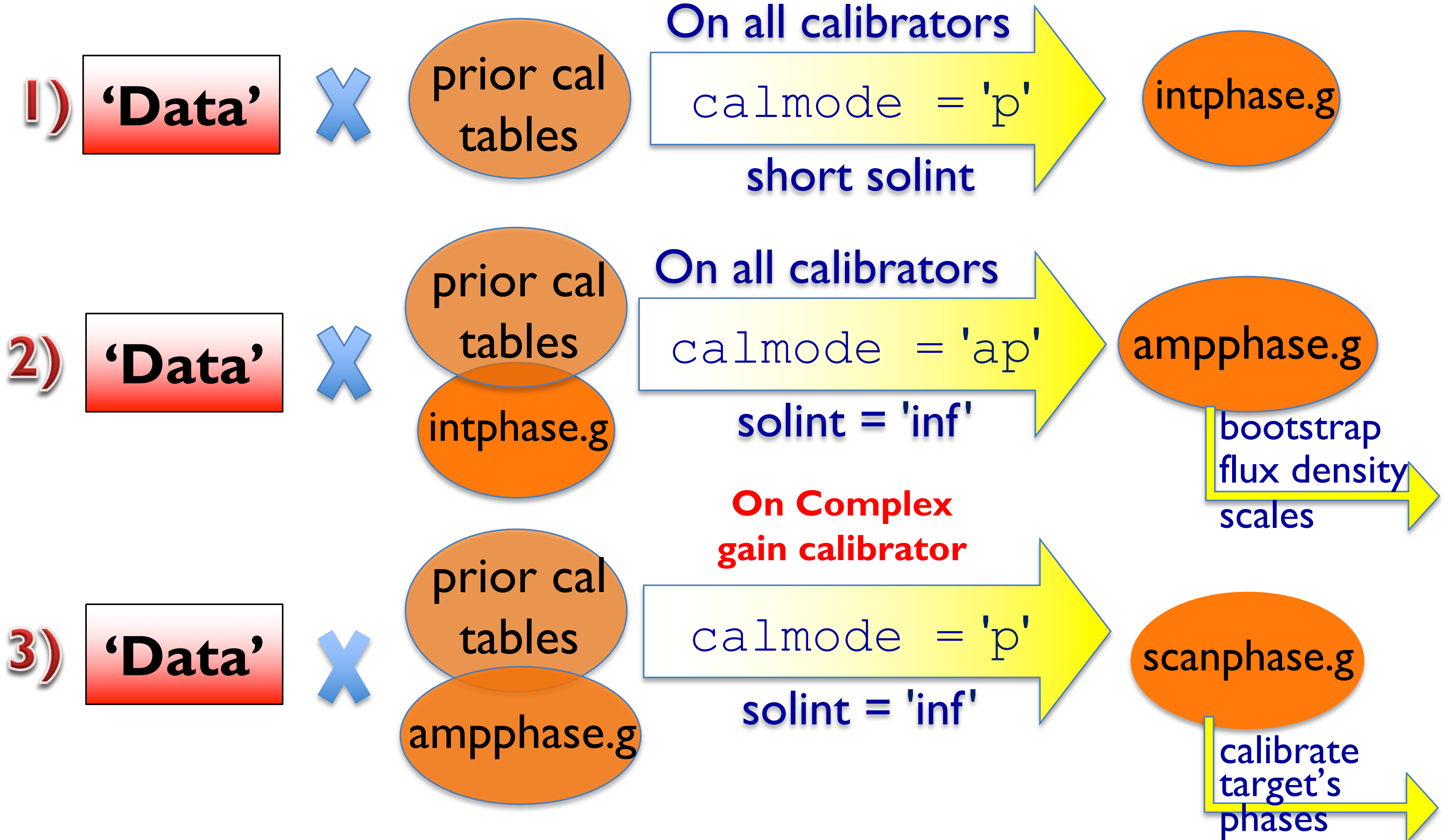
} *A priori* calibration

- ✓ Setting the flux density scale
- ✓ Delay calibration
- ✓ Pre-bandpass phase-only calibration (high-freq)
- ✓ Bandpass calibration

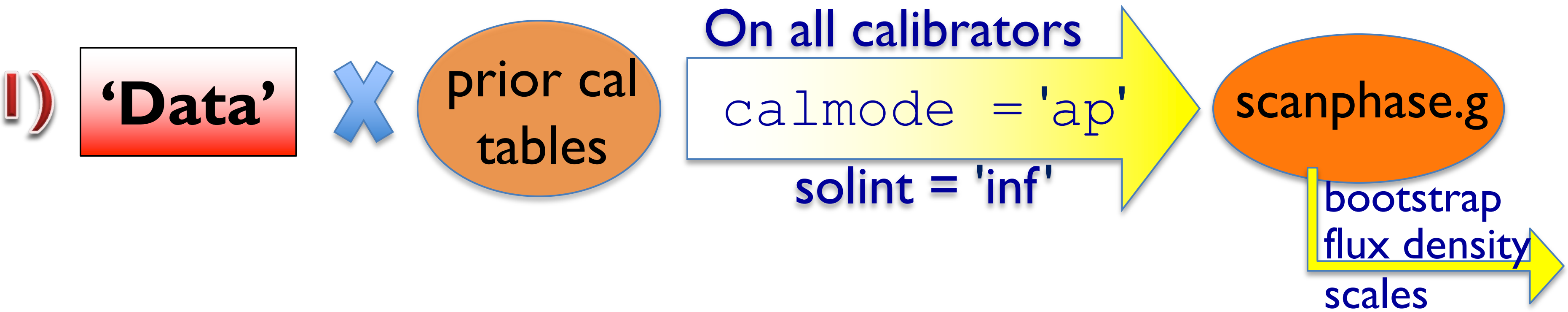
} Bandpass

- Complex gain calibration
- (Polarization Calibration)
- Setting the flux density scales of the complex gain calibrators

Complex Gain Calibration: *gaincal*, High Freq



Complex Gain Calibration: *gaincal*, Low Freq



- Examine the resulting solutions (plotms)
- If the phases show rapid variations (e.g., due to ionosphere), use the method outlined for high frequencies.

The VLA calibration pipeline always uses the high-frequency approach.

Complex gain calibration

- CASA task *gaincal*

`field`: include fluxcal *and* gain calibrator in order to (later) transfer flux scaling

`spw`: could choose to avoid low-sensitivity channels at each spw edge

```
# CASA parameters for gaincal
vis = 'my_data.ms'
caltable = 'scanphase.gcal'
field = '0,J0259+0747'
refant = 'ea10'
gaintable = ['antpos.cal', 'tecim.cal',
             'delays.cal', 'bandpass.cal']
```

<u>Important defaults</u>

`solint  = 'inf'`: yields one solution per scan on complex gain calibrator

`minsnr  =  3.0`: reject solutions at lower signal to noise than this value

`calmode = 'ap'`: perform both amplitude (`a`) and phase (`p`) calibration

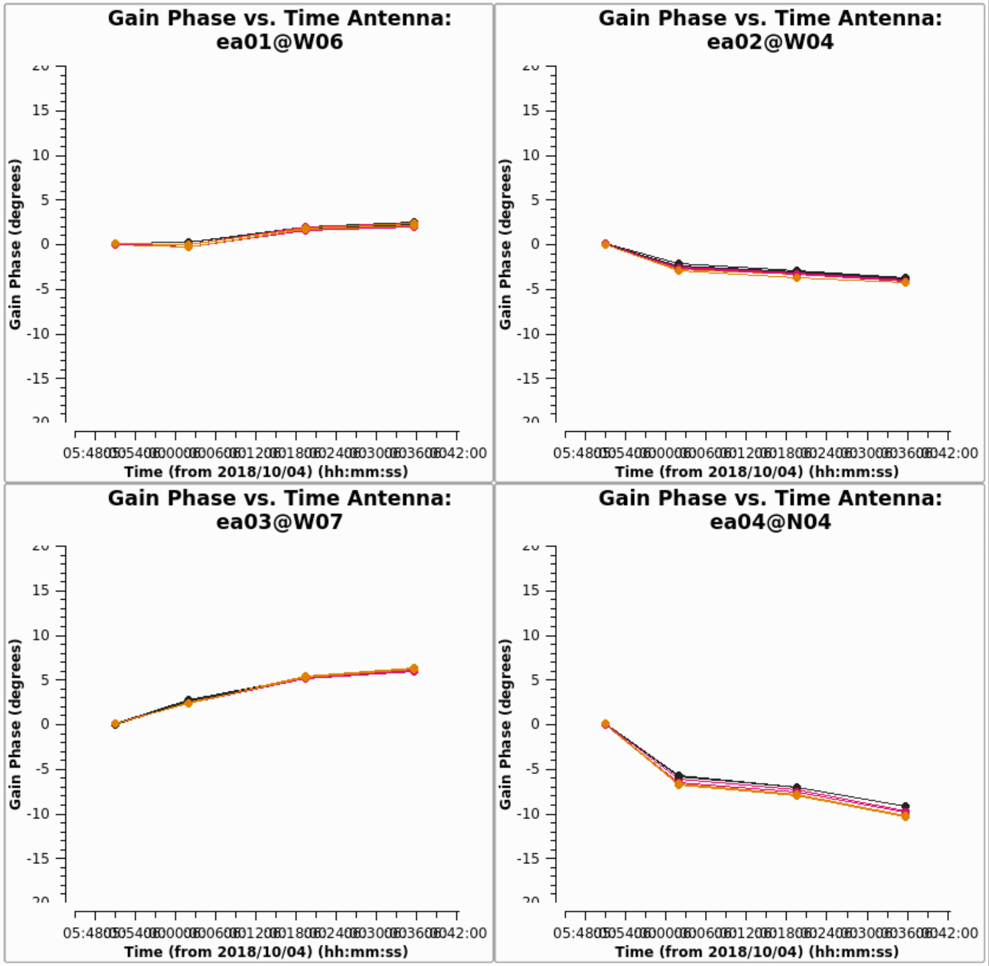
`solnorm =  False`: no need to normalize, because we're doing amplitude calibration

ON YOUR OWN

Examine complex gain cal *phase* solutions

- CASA task *plotms*

```
# CASA parameters for plotms
vis = 'scanphase.gcal'
gridrows = 2
gridcols = 2
xaxis = 'time'
yaxis = 'phase'
iteraxis = 'antenna'
coloraxis = 'spw'
xconnector = 'line'
plotrange = [-1,-1,-20,20]
```

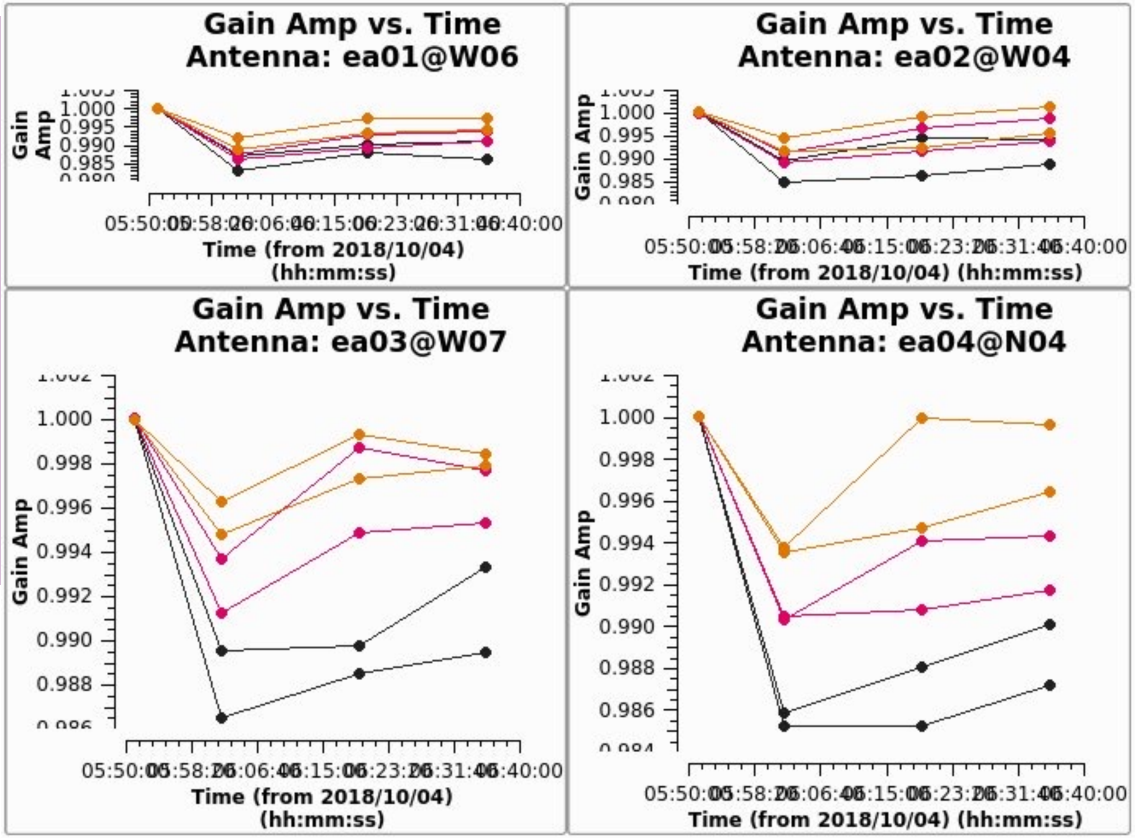


ON YOUR OWN

Examine complex gain cal *amp* solutions

- CASA task *plotms*

```
# CASA parameters for plotms
vis = 'scanphase.gcal'
gridrows = 2
gridcols = 2
xaxis = 'time'
yaxis = 'amp'
iteraxis = 'antenna'
coloraxis = 'corr'
xconnector = 'line'
plotrange = []
```



Data point with value of 1 is the flux calibrator (3C48): in this observation, bandpass cal and flux cal are the same source. (This is common).

ON YOUR OWN

Calibration

- ✓ Correcting antenna positions
- ✓ Gain Curves (high-freq)
- ✓ Opacity (high-) and Ionospheric (low-freq) corrections
- ✓ *Switched power* **
- ✓ Re-quantizer gain calibration (mostly 3-bit data)

} *A priori* calibration

- ✓ Setting the flux density scale
- ✓ Delay calibration
- ✓ Pre-bandpass phase-only calibration (high-freq)
- ✓ Bandpass calibration

} Bandpass

- ✓ Complex gain calibration
- (Polarization Calibration) ← **Frank Schinzel's talk tomorrow**
- Setting the flux density scales of the complex gain calibrators

Scaling the flux densities: CASA task *fluxscale*

Bootstrapping the flux density scales:

- We earlier used `setjy` to set the flux density values for the flux calibrator, and `gaincal` to solve for the antenna gains (`'scanphase.gcal'`) based on those values. In the `fluxscale` task, those gains are used to determine flux densities of the complex gain calibrators.
- Fits a 1st- (linear) or 2nd-order curve to each spectrum to report spectral index and curvature. Choice of fit order may depend on amount of curvature, signal-to-noise of calibrator.
- Results can be stored in a variable or written to a file.

`reference` = name of flux density calibrator
`transfer` = name or fields of complex gain calibrators
`fitorder` = **`N`** # for Nth order polynomial fit to spectrum (default is **`1`**)
`listfile` = name of output file to store results (optional)

Scaling the flux densities: CASA task *fluxscale*

Fluxscale produces a new calibration table but there are two options:

```
fluxtable = '<output cal table>'
incremental = True or False
```

If `incremental = False`:

The `<output cal table>` *replaces* the input '`ap`' table.

If `incremental = True`:

The `<output cal table>` contains *only* the scaling factors, and must be used alongside the input '`ap`' table when applying calibration.

Which approach to use is purely a matter of personal preference.

Bootstrap the flux density, fit spectrum

ON YOUR OWN

- CASA task *fluxscale*

```
# CASA parameters for fluxscale
vis = 'my_data.ms'
caltable = 'scanphase.gcal'
fluxtable = 'fluxscale.cal'
reference = '0137+331=3C48'
transfer = ['J0259+0747']
fitorder = 1
incremental = False
```

Output can be captured in a variable, e.g.: `output = fluxscale(<inputs>)`

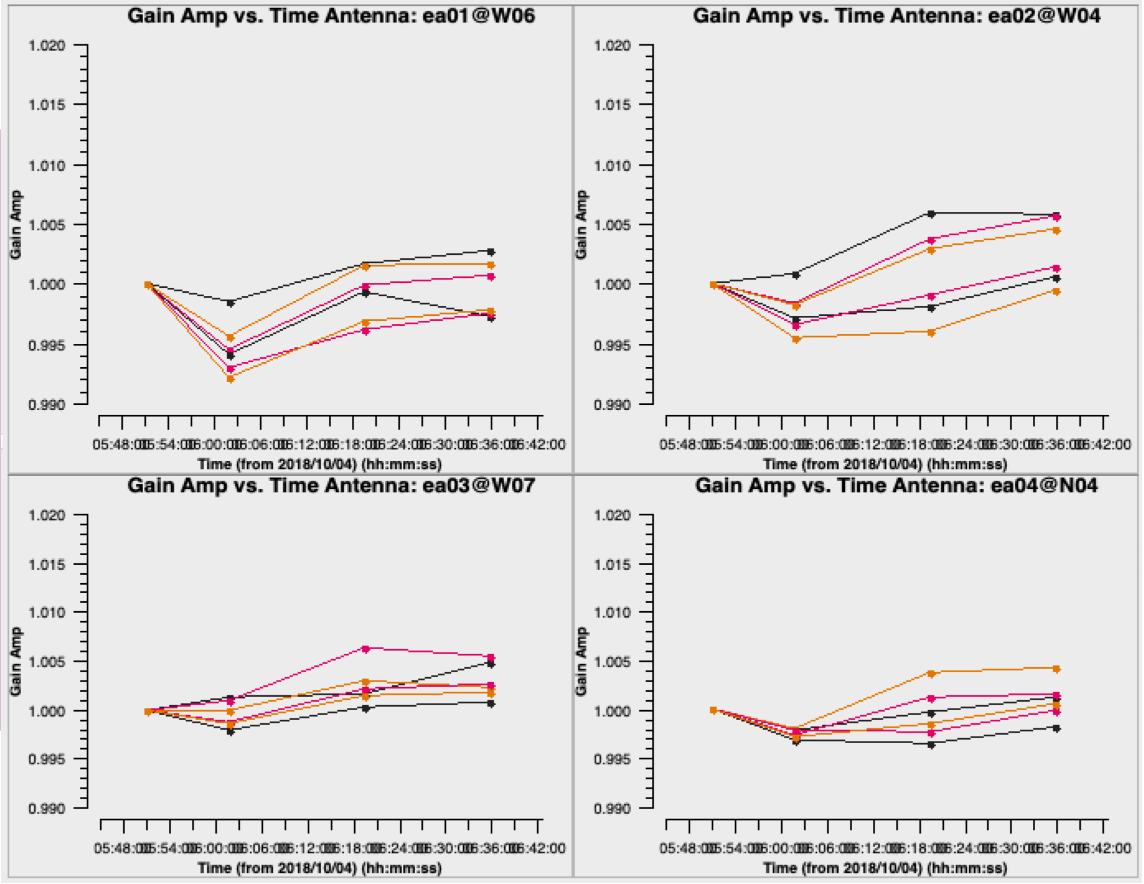
Results reported in casalogger:

```
 Flux density for J0259+0747 in SpW=0 (freq=3.063e+09 Hz) is: 0.977185 +/- 0.000951276 (SNR = 1027.24, N = 54)
 Flux density for J0259+0747 in SpW=1 (freq=3.191e+09 Hz) is: 0.985048 +/- 0.000940982 (SNR = 1046.83, N = 54)
 Flux density for J0259+0747 in SpW=2 (freq=3.319e+09 Hz) is: 0.99209 +/- 0.00099727 (SNR = 994.806, N = 54)
 Fitted spectrum for J0259+0747 with fitorder=1: Flux density = 0.98476 +/- 0.00013787 (freq=3.18929 GHz) spidx:
Storing result in fluxscale.cal
```

Examine rescaled amplitude solutions

- CASA task *plotms*

```
# CASA parameters for plotms
vis = 'fluxscale.cal'
xaxis = 'time'
yaxis = 'amp'
gridrows = 2
gridcols = 2
coloraxis = 'spw'
iteraxis = 'antenna'
yselfscale = True
xconnector = 'line'
```



ON YOUR OWN

Calibration

- ✓ Correcting antenna positions
- ✓ Gain Curves (high-freq)
- ✓ Opacity (high-) and Ionospheric (low-freq) corrections
- ✓ *Switched power* **
- ✓ Re-quantizer gain calibration (mostly 3-bit data)

} *A priori* calibration

- ✓ Setting the flux density scale
- ✓ Delay calibration
- ✓ Pre-bandpass phase-only calibration (high-freq)
- ✓ Bandpass calibration

} Bandpass

- ✓ Complex gain calibration
- ✓ (Polarization Calibration) ← **Frank Schinzel's talk tomorrow**
- ✓ Setting the flux density scales of the complex gain calibrators

Applying the calibration

- First apply calibration not to the targets, but to the calibrators themselves.
  - Looking at calibrated visibilities for the calibrators is a good way to confirm that the calibration is good and to identify bad data that may have been missed before (e.g. RFI).

- Multiple calibrators in the data?
  - Simplest approach is to use one run of the *applycal* task for each calibrator

Apply the calibration: *flux/bandpass calibrator*

- CASA task *applycal*

`gaintable`: the calibration tables

`gainfield`: fields from the above tables (if table has solutions from >1 source)

`interp`: apply *`nearest`* solution? or interpolate between solutions (*`linear`*)?

`calwt`: use system calibration to weight the data? not yet for VLA data! (`False`)

```
# CASA parameters for applycal: apply calibration to bandpass/flux cal
vis = 'my_data.ms'
field = '0137+331=3C48'
gaintable = ['antpos.cal', 'tecim.cal', 'delays.cal',
             'bandpass.cal', 'fluxscale.cal']
gainfield = ['', '', '', '', '0137+331=3C48']
interp = ['', '', '', '', 'nearest']
calwt = False
```

ON YOUR OWN

Apply the calibration: *gain calibrators*

- CASA task *applycal*

Now apply the calibration to each of the phase calibrators. Most of the input parameters remain the same...

```
# CASA parameters for applycal:  apply calibration to gain calibrator
vis = 'my_data.ms'
field = 'J0259+0747'
gaintable = ['antpos.cal', 'tecim.cal', 'delays.cal',
             'bandpass.cal', 'fluxscale.cal']
gainfield = ['', '', '', '', 'J0259+0747']
interp = ['', '', '', '', 'nearest']
calwt = False
```

ON YOUR OWN

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

Flag, if needed, and re-calibrate.

Apply the calibration: *targets*

- CASA task *applycal*

`gainfield`: apply the solution from the appropriate complex gain calibrator

`interp`: use *`linear`* interpolation to interpolate in time between the complex gain calibration solutions

```
# CASA parameters for applycal: apply calibration to target
vis = 'my_data.ms'
field = '3C75'
gaintable = ['antpos.cal', 'tecim.cal', 'delays.cal',
             'bandpass.cal', 'fluxscale.cal']
gainfield = ['', '', '', '', 'J0259+0747']
interp = ['', '', '', '', 'linear']
calwt = False
```

ON YOUR OWN

Split target source(s) into their own MS

- CASA task *mstransform*

- Split target source(s) using corrected column.
- Optionally:
  - apply time and/or frequency averaging
  - choose certain spws/channels

```
# CASA parameters for mstransform or split
vis = 'my_data.ms'
outputvis = '3C75.ms'
field = '3C75'
correlation = 'RR,LL'
datacolumn = 'corrected'
```

ON YOUR OWN

- The split out data will occupy the 'data' column in the output MS.
- This step is recommended before re-weighting the data (`statwt`) and before imaging.
- Note: for full-polarization data that has not been polarization-calibrated, use: `correlation = 'RR,LL'`

Re-weight the visibilities

- CASA task *statwt*

```
# CASA parameters for statwt
vis = '3C75.ms'
datacolumn = 'data'
```

- Data weights are initialized to be based on channel bandwidth and integration-time ($2\Delta\nu\Delta\tau$).
- *statwt* re-weights the visibilities according to their scatter:
  - down-weight underperforming antennas
  - down-weight frequency ranges affected by RFI
- Use on *fully-calibrated* data!

- *Note for spectral lines*:
  - use `fitspw` parameter to exclude strong lines

ON YOUR OWN

The VLA Calibration Pipeline

- Performs basic flagging and calibration using CASA.
- Primarily designed for Stokes `I` continuum data.
- To run successfully, the scan intents in the observation scheduling block *must* be set correctly.
- Information is at:

https://science.nrao.edu/facilities/vla/data-processing/pipeline

- More details later ⟵ **Drew Medlin's talk tomorrow**

Science-Ready Data Products (SRDP)

- Provide calibrated (and eventually imaged) PI observations
  → users can focus on their science!
- Intended ultimately for all NRAO instruments

- SRDP project will cover increasing functionality over the next several years. Currently available for:
  - C-band and higher frequencies (≥ 4 GHz)
  - continuum science only
  - these standard flux/BP/delay cals only: 3C286, 3C147

Observing setups *must* follow all VLA observing guidelines and be pipeline compatible (e.g. scan intents, calibrator cycles)

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