



ALMA pipeline: Calibration and imaging

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Outline

- ▶ Introduction to ALMA
- ▶ General pipeline (PL) processing
- ▶ Pipeline products
- ▶ Quality of calibration

ALMA collaborators

- ▶ Where?
 - ▶ Atacama desert in northeast Chile
 - ▶ Elevation ~ 5000m
- ▶ Three major partners (EA, EU, NA)
- ▶ Taiwan participates through East Asia



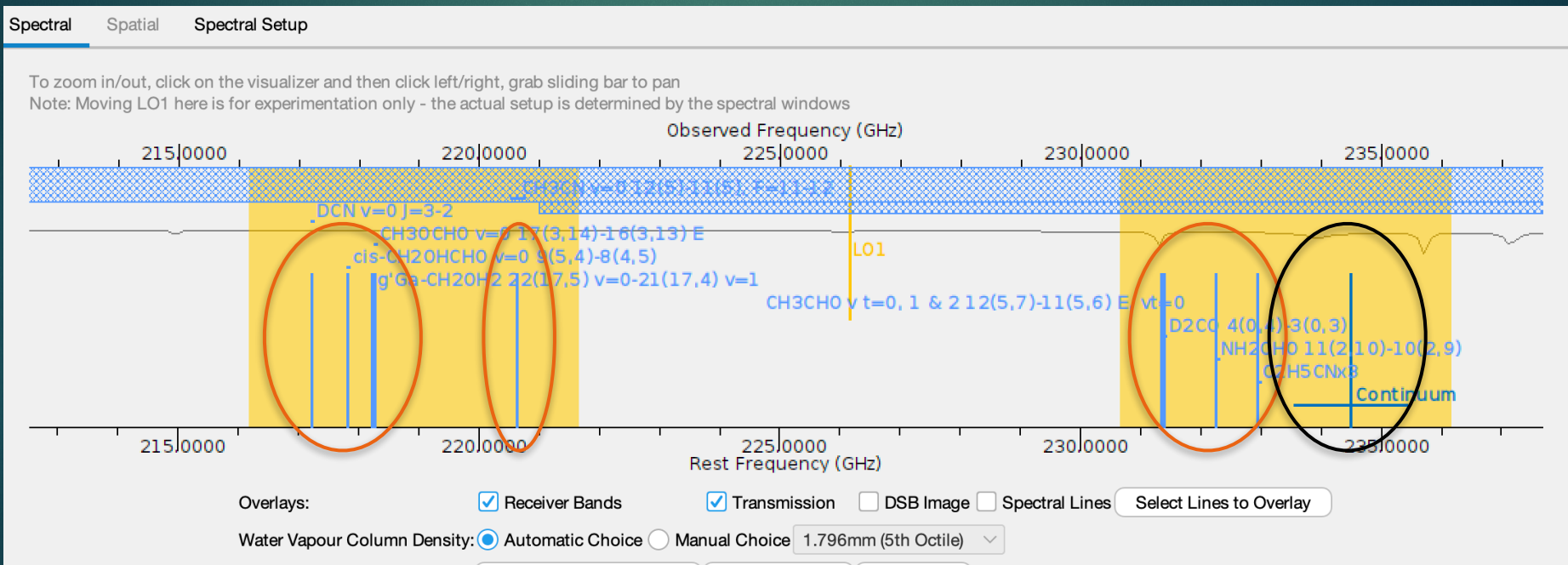
ALMA components

- ▶ 7-m Array (ACA, 8)
- ▶ 12-m Array (44)
- ▶ Total power (TP) array (Single dish 4)



Observing modes

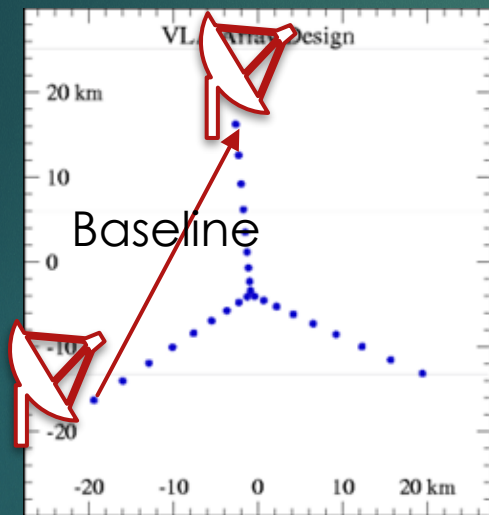
- ▶ Continuum and spectral lines
- ▶ Polarization
- ▶ Line scan



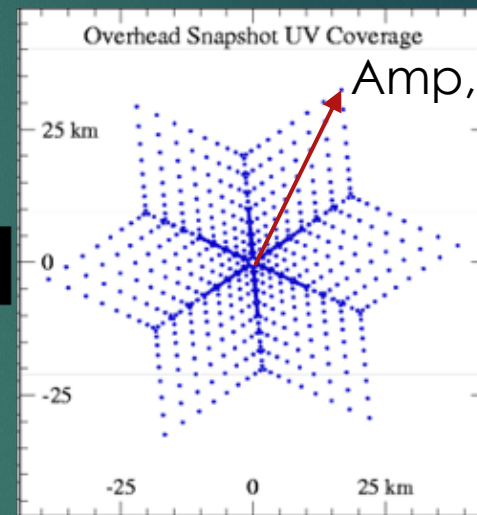
Continuum window: aim for 2D spatial image for continuum emission (to be integrated)
Line windows: aim for a 3D cube (+frequency) for molecular line emission

Data structure of interferometer

- ▶ Visibility (UV table, Measurement sets)
 - ▶ Inverse FT -> Spatial distribution (sky image)
 - ▶ Amplitude (Brightness) + Phase (position)



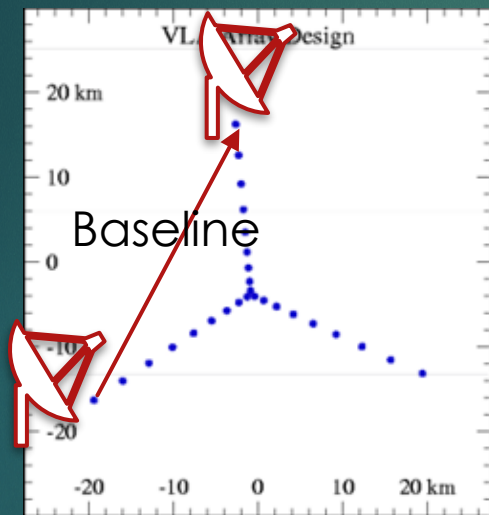
V



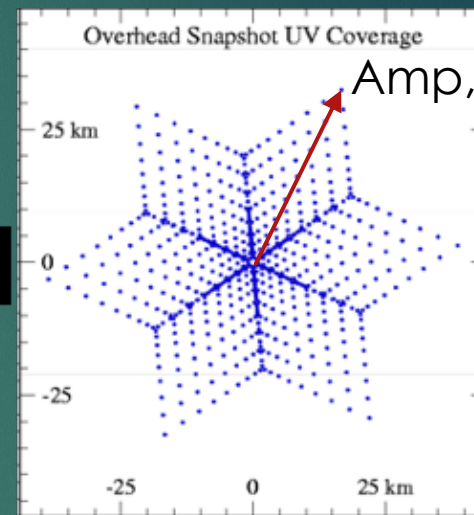
U

Data structure of interferometer

- ▶ Visibility (UV table, Measurement sets)
 - ▶ Inverse FT -> Spatial distribution (sky image)
 - ▶ Amplitude (Brightness) + Phase (position)



V



U

- ▶ Calibration:
 - ▶ Bandpass: calibrate bandpass response (at frequency domain)
 - ▶ Amplitude: calibrate flux (brightness)
 - ▶ Phase: calibrate the time domain variations

General pipeline processing

The Pipeline (PL):

- ▶ The kind of Scheduling Block (SB)
 - ▶ how many Execution Blocks (EB) are QA0_PASS
- ▶ Selects recipe for calibration
- ▶ Applies heuristics for flags, bad gains, etc.
- ▶ Runs imaging stage (if set)
- ▶ Creates weblog with results
- ▶ Exports products in *fits* format

PL does not:

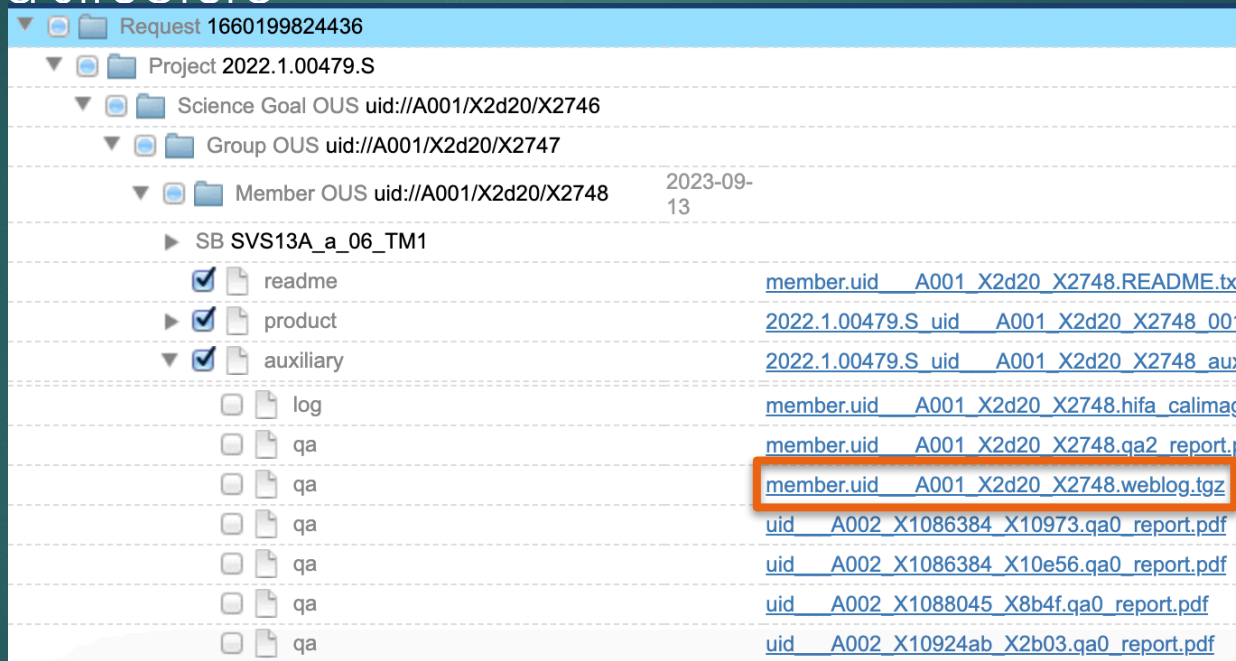
- ▶ iterate, e.g. to find best results
- ▶ Have much room for customization
- ▶ **double check things**, in case you wrongly modify things
- ▶ require much attention from user

Archival package

- ▶ Final images for PI (.fits)
- ▶ Calibration scripts (.py)
- ▶ README (text)
- ▶ **Weblog** (html)
- ▶ RAW data (asdm)

Open weblog (recommended way)

- ▶ Pipeline used to process most (>95%) of ALMA PI data
- ▶ Data structure



- ▶ `casa --pipeline` In the folder where html is
- ▶ `CASA <1>: h_weblog()`

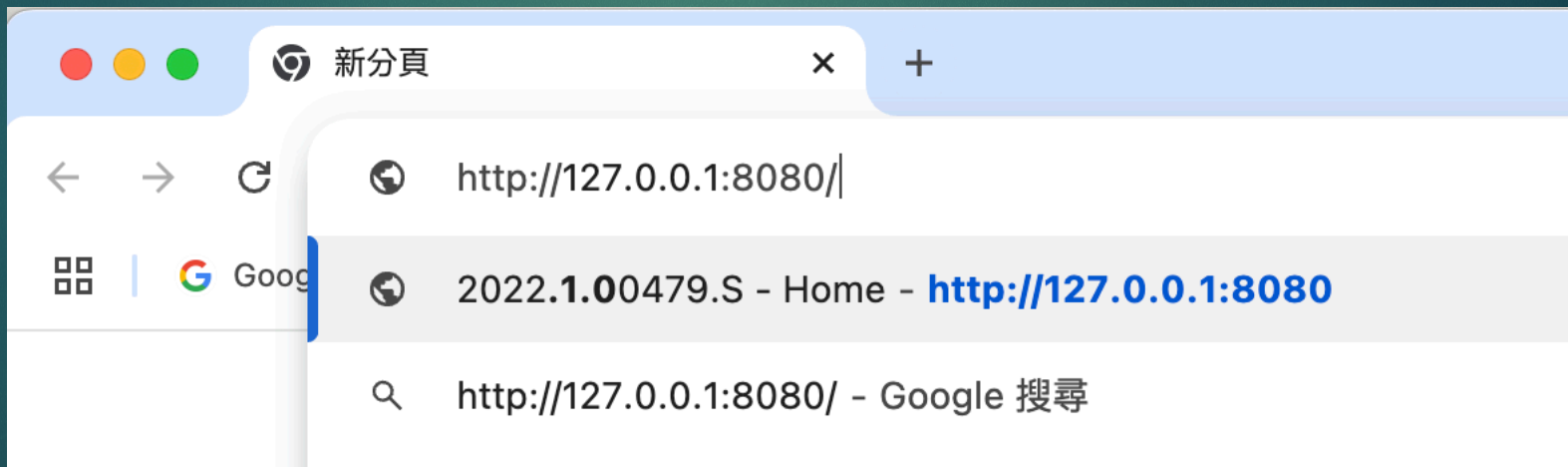
Open weblog (alternative way)

- ▶ Data structure

```
(base) MacBook-Pro-7:html inchone_1$ python3 -m http.server 8080 --bind 127.0.0.1  
Serving HTTP on 127.0.0.1 port 8080 (http://127.0.0.1:8080/) ...
```

in where the index.html is (under html)

- ▶ Open your browser:





Structure of a pipeline package

What and Why weblog

- ▶ What is weblog
 - ▶ After PL calibration, where the details of the procedure is saved and can be reviewed
- ▶ Why weblog
 - ▶ To check the data quality
 - ▶ Record details of observations and calibrations
- ▶ To write the “observations” in your paper...

The Weblog

Topics



[Home](#) [By Topic](#) [By Task](#)

2022.1.00479.S

Observation Overview

Project	uid://A001/X15ba/X7aa
Principal Investigator	inchone
OUS Status Entity id	uid://A001/X2d20/X2748
Observation Start	2023-06-10 12:58:11 UTC
Observation End	2023-06-23 12:40:01 UTC

Pipeline Summary

Pipeline Version	2022.2.0.68 (documentation)
CASA Version	6.4.1.12 (environment)
IERSeop2000 Version	0001.0172 (last date: 2023-06-28 00:00:00)
IERSpredict Version	0623.1284 (last date: 2023-11-17 00:00:00)
Pipeline Start	2023-08-25 18:14:44 UTC
Execution Duration	10 days, 3:20:30

Observation Summary

Measurement Set	Receivers	Num Antennae	Time (UTC)			Baseline Length			Size
			Start	End	On Target	Min	Max	RMS	
Observing Unit	Measurement set (observed visibility) a_06_TM1								
Session: session_1 ACS Version: 38083c1, Build Version: ONLINE-CYCLE9-B-13-2022-10-21-28-00-00									
uid__A002_X1086384_X10973.ms	ALMA Band 6	44	2023-06-10 12:58:11	2023-06-10 14:38:24	0:48:32	92.1 m	4.6 km	1.5 km	374.0 GiB
uid__A002_X1086384_X10973_targets.ms	ALMA Band 6	44	2023-06-10 13:09:32	2023-06-10 14:38:01	0:48:05	92.1 m	4.6 km	1.5 km	220.9 GiB
uid__A002_X1086384_X10973_targets_line.ms	ALMA Band 6	44	2023-06-10 13:09:32	2023-06-10 14:38:01	0:48:05	92.1 m	4.6 km	1.5 km	220.9 GiB
uid__A002_X1086384_X10e56.ms	ALMA Band 6	44	2023-06-10 14:44:43	2023-06-10 16:23:54	0:48:37	92.1 m	4.6 km	1.5 km	373.7 GiB
uid__A002_X1086384_X10e56_targets.ms	ALMA Band 6	44	2023-06-10 14:55:23	2023-06-10 16:23:33	0:48:05	92.1 m	4.6 km	1.5 km	220.9 GiB
uid__A002_X1086384_X10e56_targets_line.ms	ALMA Band 6	44	2023-06-10 14:55:23	2023-06-10 16:23:33	0:48:05	92.1 m	4.6 km	1.5 km	220.9 GiB
Scheduling Block ID: uid://A001/X2d20/X2743 Scheduling Block Name: SVS13A_a_06_TM1									
Session: session_3 ACS Version: e6e01f7, Build Version: ONLINE-CYCLE9-B-17-2023-06-16-05-00-00									

The Weblog -- an EB

Measurement set (observed visibility)



- Session: session_1
 - uid__A002_X1086384_X10973.ms
 - uid__A002_X1086384_X10973_targets.ms
 - uid__A002_X1086384_X10973_targets_li
 - uid__A002_X1086384_X10e56.ms
 - uid__A002_X1086384_X10e56_targets.ms
 - uid__A002_X1086384_X10e56_targets_li
- Session: session_3
 - uid__A002_X10924ab_X2b03.ms
 - uid__A002_X10924ab_X2b03_targets.ms
 - uid__A002_X10924ab_X2b03_targets_li

Overview of 'uid__A002_X1086384_X10973.ms'

Observation Execution Time

Start Time	2023-06-10 12:58:11
End Time	2023-06-10 14:38:24
Total Time on Source	1:25:59
Total Time on Science Target	0:48:32

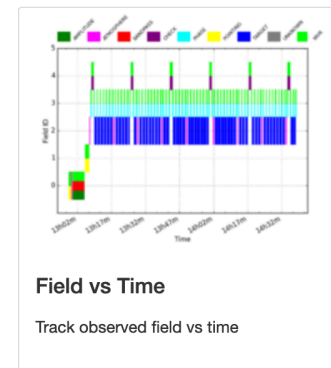
[LISTOBS OUTPUT](#)

Spatial Setup

Science Targets	'SVS13A'
Calibrators	'J0324+3410', 'J0336+3218', 'J0357+2319' and 'J0423-0120'

Antenna Setup

Min Baseline	92.1 m	Min Elevation	28.48 degrees
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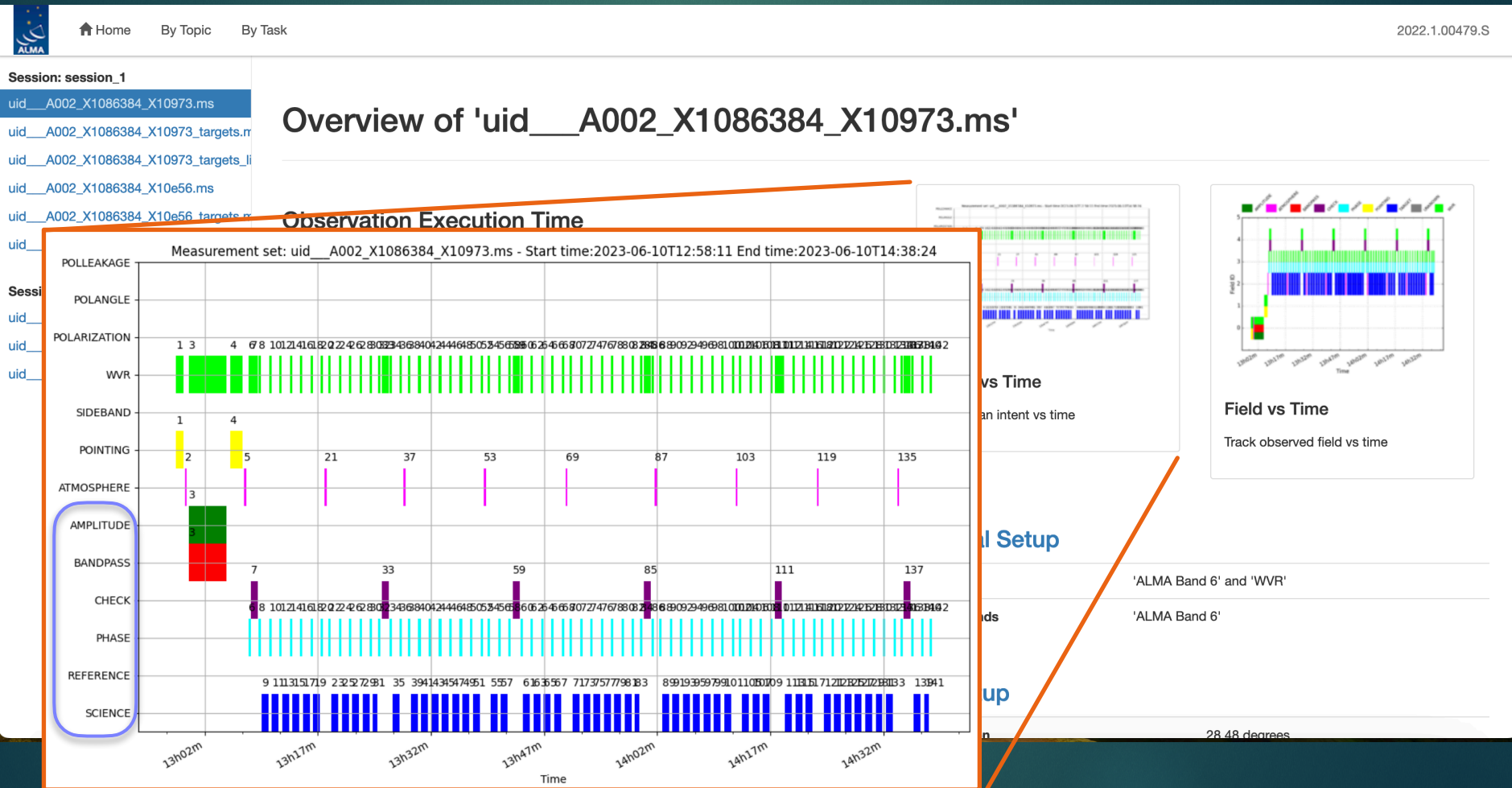
Spectral Setup

All Bands	'ALMA Band 6' and 'WVR'
Science Bands	'ALMA Band 6'

Sky Setup

The Weblog -- an EB

Measurement set (observed visibility)



The Weblog -- an EB

All
clickable

Spatial Setup

Science Targets 'NGC4303'
Calibrators 'Callisto', 'J1222+0413' and 'J1229+0203'

Spectral Setup

All Bands 'ALMA Band 6'
Science Bands 'ALMA Band 6'

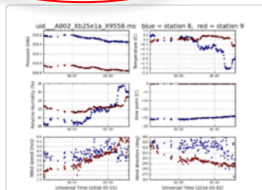
Antenna Setup

Min Baseline 8.9 m
Max Baseline 45.0 m

Sky Setup

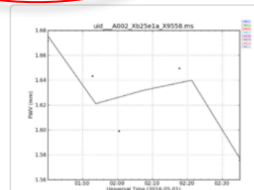
Min Elevation 55.43 degrees
Max Elevation 63.93 degrees

Weather



Weather plot

PWV



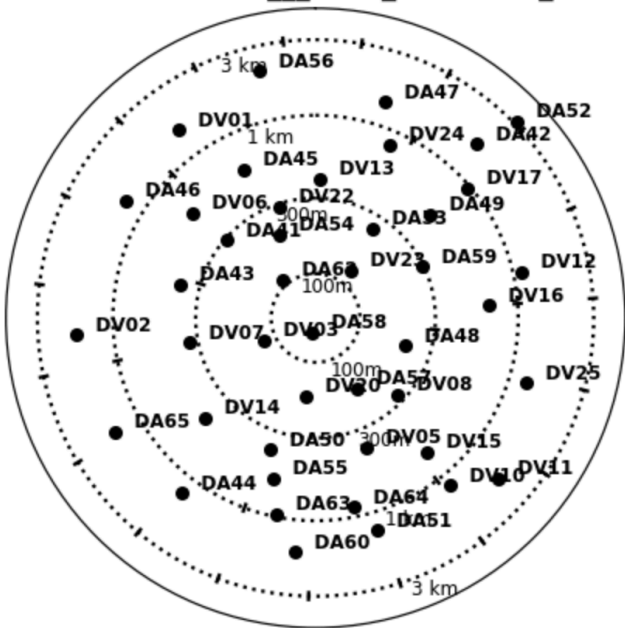
PWV plot

Scans

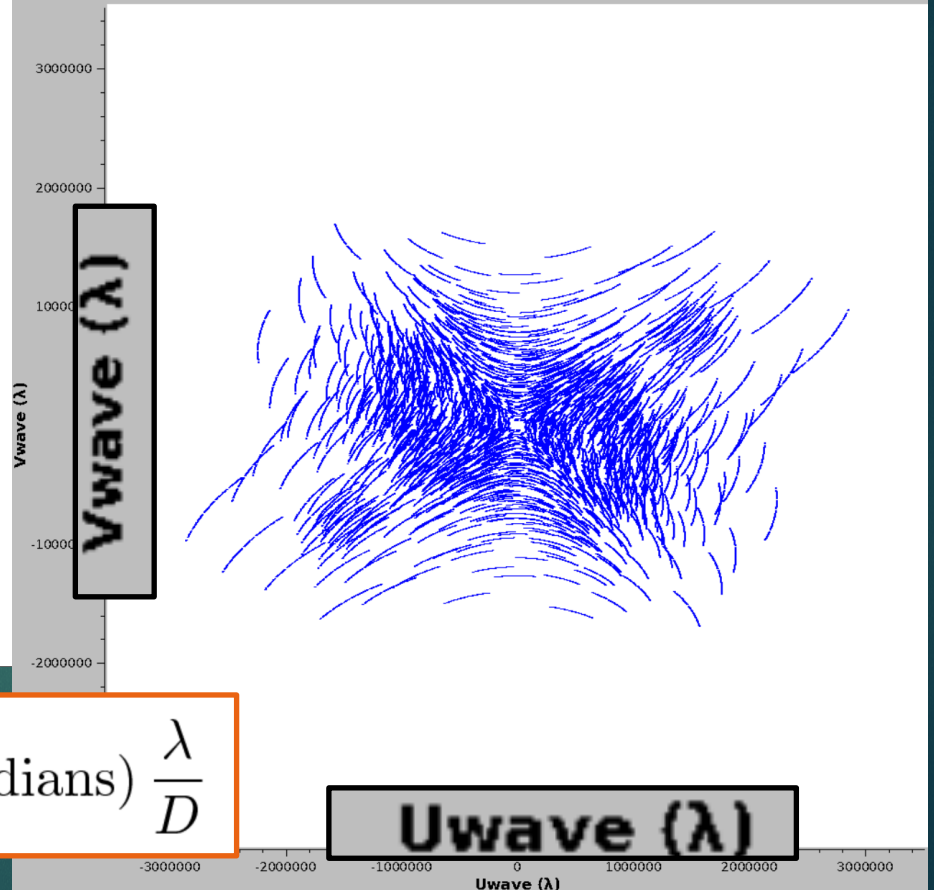
Configuration used (antenna array positions)

Antenna Positions for uid__A002_X1086384_X10973.ms

DA41: 0.3 km, -49°
 DA42: 1.7 km, 148°
 DA43: 0.4 km, -76°
 DA44: 1.3 km, -143°
 DA45: 0.6 km, -26°
 DA46: 1.4 km, -58°
 DA47: 1.4 km, 18°
 DA48: 0.2 km, 107°
 DA49: 0.5 km, 48°
 DA50: 0.4 km, -161°
 DA51: 1.3 km, 164°
 DA52: 3.2 km, 46°
 DA53: 0.2 km, 33°
 DA54: 0.2 km, -23°
 DA55: 0.6 km, -165°
 DA56: 2.1 km, -13°
 DA57: 0.2 km, 149°
 DA58: 0.1 km, -168°
 DA59: 0.3 km, 64°
 DA60: 1.6 km, -175°
 DA62: 0.1 km, -40°
 DA63: 1.0 km, -169°
 DA64: 0.9 km, 169°
 DA65: 1.5 km, -120°
 DV01: 1.5 km, -36°
 DV02: 1.7 km, -94°
 DV03: 0.1 km, -113°
 DV05: 0.4 km, 159°
 DV06: 0.6 km, -50°
 DV07: 0.3 km, -101°
 DV08: 0.3 km, 133°
 DV10: 1.2 km, 141°
 DV11: 1.8 km, 131°
 DV12: 1.1 km, 78°
 DV13: 0.4 km, 2°
 DV14: 0.5 km, -132°
 DV15: 0.7 km, 140°
 DV16: 0.7 km, 86°
 DV17: 1.0 km, 50°
 DV20: 0.2 km, -173°
 DV22: 0.3 km, -18°
 DV23: 0.1 km, 37°
 DV24: 0.8 km, 23°
 DV25: 1.3 km, 107°



Initial UV coverage for uid__A002_X1086384_X10973.ms

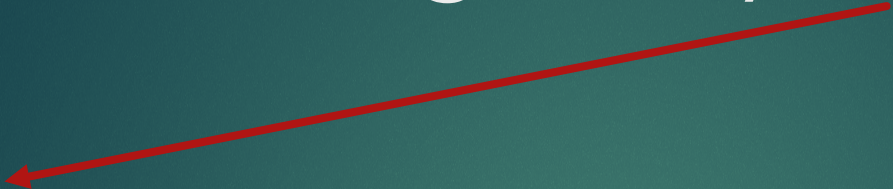


Diffraction limit

$$\theta = (1.22 \text{ radians}) \frac{\lambda}{D}$$

Uwave (λ)

The Weblog -- by topic



QA Scores: Lowest by Topic

Topic	Lowest Scoring Task		Min Score
Data Sets	19. hif_applycal : Apply calibrations from context	Phase vs frequency zero point outliers	 0.90
Calibration	17. hifa_timegaincal : Gain calibration	Potential phase offset outliers	 0.50
Flagging	19. hif_applycal : Apply calibrations from context	Phase vs frequency zero point outliers	 0.90
Imaging	25. hif_checkproductsizes : Check product size	Size was mitigated	 0.50
Miscellaneous	5. hif_refant : Select reference antennas		 1.00

Task Notifications: Warnings and Errors

Stage	Task	Type	Message
10	hif_lowgainflag	Warning	uid__A002_X1086384_X10973.ms - the following antennas have been fully flagged in one or more spws, and moved to the end of the refant list: DV07 and DV05
10	hif_lowgainflag	Warning	uid__A002_X1086384_X10e56.ms - the following antennas have been fully flagged in one or more spws, and moved to the end of the refant list: DV07, DA65 and DV05
10	hif_lowgainflag	Warning	uid__A002_X10924ab_X2b03.ms - the following antennas have been fully flagged in one or more spws, and moved to the end of the refant list: DV05
31	hif_findcont	Warning	Field SVS13A, spw 27: LowBW
31	hif_findcont	Warning	Field SVS13A, spw 33: LowBW
31	hif_findcont	Warning	Field SVS13A, spw 41: LowSpread
31	hif_findcont	Warning	Field SVS13A, spw 43: LowBW

Flagging summary

Flagging percentages for Source name: J0336+3218, Intents: PHASE,WVR

spw	DA41	DA42	DA43	DA44	DA45	DA46	DA47	DA48	DA49	DA50	DA51	DA64	DA65	DV01	DV02	DV03	DV05	DV06	DV07	DV08	DV10	DV11
25	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	100.000	6.824	100.000	6.824	6.824	6.824
27	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	100.000	6.824	100.000	6.824	6.824	6.824
29	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	100.000	6.824	100.000	6.824	6.824	6.824
31	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	6.824	100.000	6.824	100.000	6.824	6.824	6.824
33	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	100.000	4.551	4.551	4.551
35	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	4.551	100.000	4.551	4.551	4.551

Flagging percentages for Source name: SVS13A, Intents: ATMOSPHERE,TARGET

spw	DA41	DA42	DA43	DA44	DA45	DA46	DA47	DA48	DA49	DA50	DA51	DA64	DA65	DV01	DV02	DV03	DV05	DV06	DV07	DV08	DV10	DV11
25	6.840	6.840	6.840	6.840	6.840	6.935	6.935	6.840	6.935	6.840	6.935	6.840	6.840	6.840	6.840	6.840	100.000	6.840	100.000	6.840	6.840	6.840
27	6.840	6.840	6.840	6.840	6.840	6.935	6.935	6.840	6.935	6.840	6.935	6.840	6.840	6.840	6.840	6.840	100.000	6.840	100.000	6.840	6.840	6.840
29	6.840	6.840	6.840	6.840	6.840	6.935	6.935	6.840	6.935	6.840	6.935	6.840	6.840	6.840	6.840	6.840	100.000	6.840	100.000	6.840	6.840	6.840
31	6.840	6.840	6.840	6.840	6.840	6.935	6.935	6.840	6.935	6.840	6.935	6.840	6.840	6.840	6.840	6.840	100.000	6.840	100.000	6.840	6.840	6.840
33	4.567	4.567	4.567	4.567	4.567	4.665	4.665	4.567	4.665	4.567	4.665	4.567	4.567	4.567	4.567	4.567	4.567	4.567	100.000	4.567	4.567	4.567
35	4.567	4.567	4.567	4.567	4.567	4.665	4.665	4.567	4.665	4.567	4.665	4.567	4.567	4.567	4.567	4.567	4.567	4.567	100.000	4.567	4.567	4.567

The Weblog -- by task



ALMA

Home By Topic **By Task**

2022.1.00479.S

Task Summaries

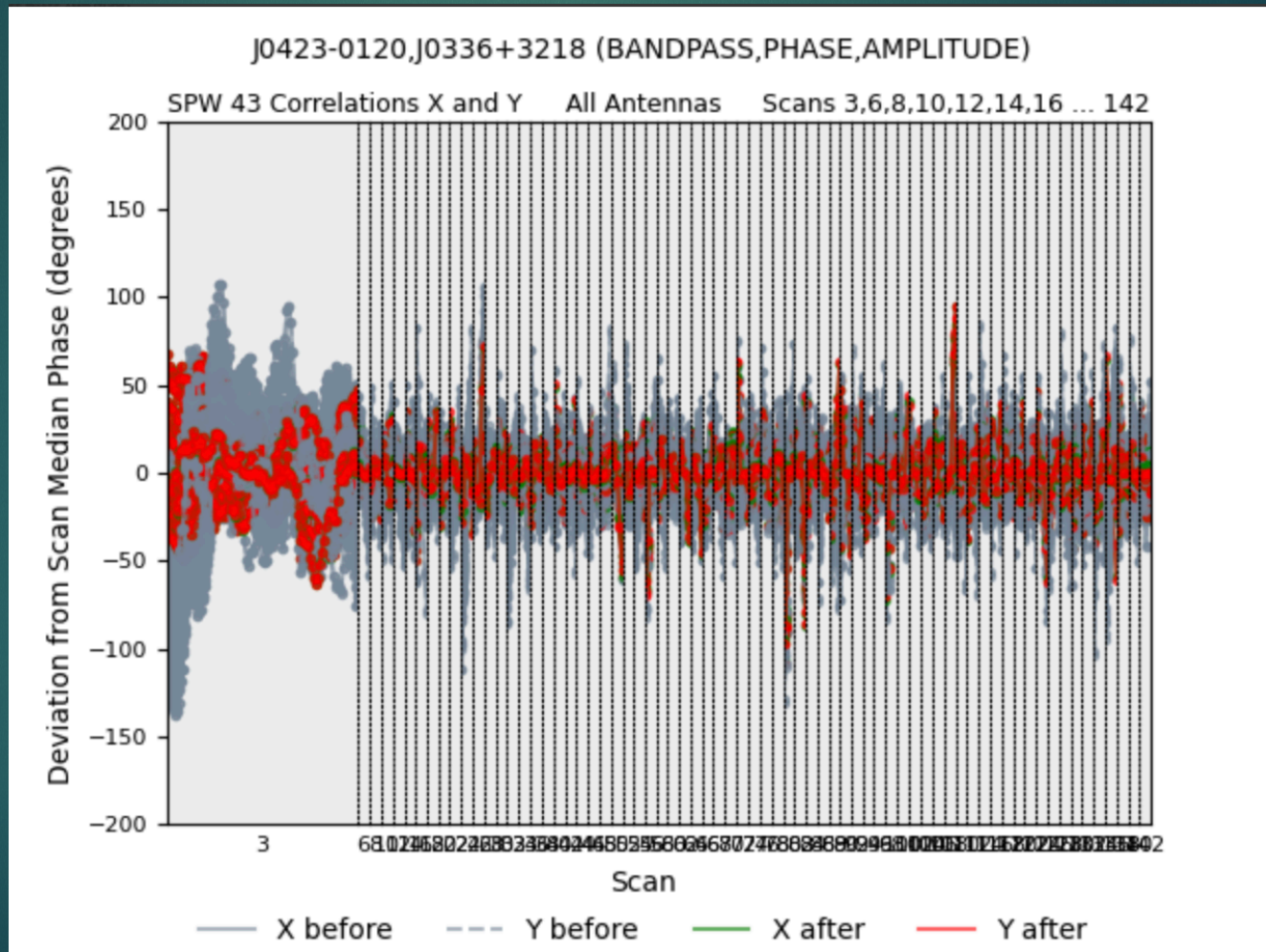
Task	QA Score	Duration
1. hifa_importdata : Register measurement sets with the pipeline	1.00	1:58:33
2. hifa_flagdata : ALMA deterministic flagging	1.00	8:24:51
3. hifa_fluxcalflag : Flag spectral features in solar system flux calibrators	1.00	0:00:09
4. hif_rawflagchans : Flag channels in raw data	1.00	0:58:38
5. hif_refant : Select reference antennas	1.00	0:08:54
6. h_tsyscal : Calculate Tsys calibration	1.00	0:30:13
7. hifa_tsysflag : Flag Tsys calibration	0.99	0:31:16
8. hifa_antpos : Correct for antenna position offsets	Nonzero antenna position offsets 0.90	0:00:15
9. hifa_wvrgcalflag : Calculate and flag WVR calibration	1.06x improvement 0.77	3:26:19
10. hif_lowgainflag : Flag antennas with low gain	1.00	1:52:56
11. hif_setmodels : Set calibrator model visibilities	1.00	5:35:52
12. hifa_bandpassflag : Phase-up bandpass calibration and flagging	1.00	4:55:40
13. hifa_bandpass : Phase-up bandpass calibration	1.00	3:05:04



Assessing calibration quality

Calibration - water vapor radiometer (wvr) (task 9)

Ideally,
red should
have less
scatter



Calibration - wvr (task 9)

Per-antenna plots available

Click to filter/extract plot

[uid__A002_X1086384_X10e56.ms](#)

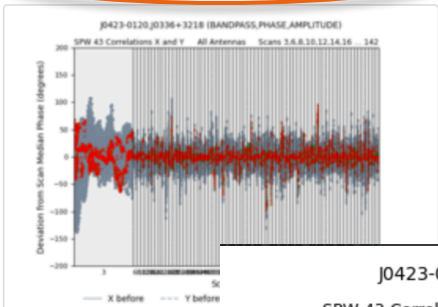
Antenna filter

DA43

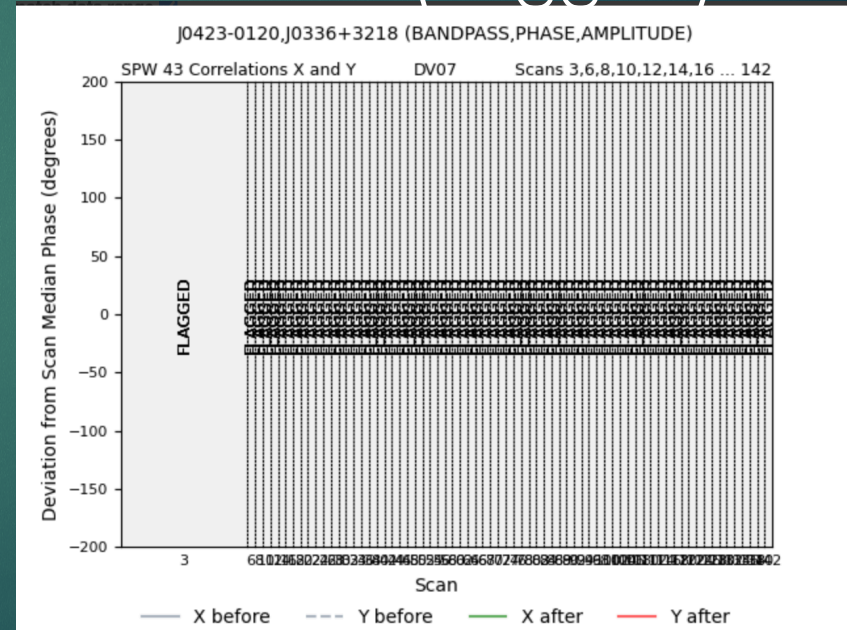
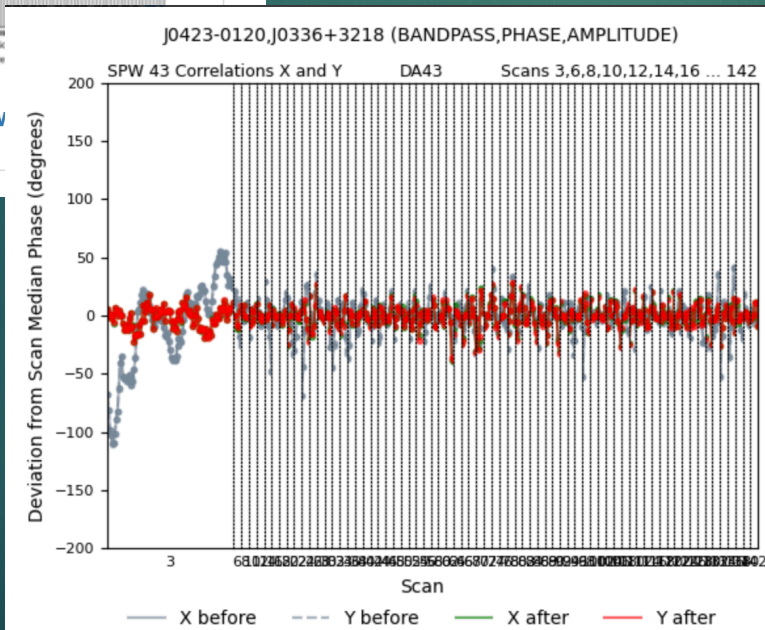
DV07

DV43

DV07 (flagged)



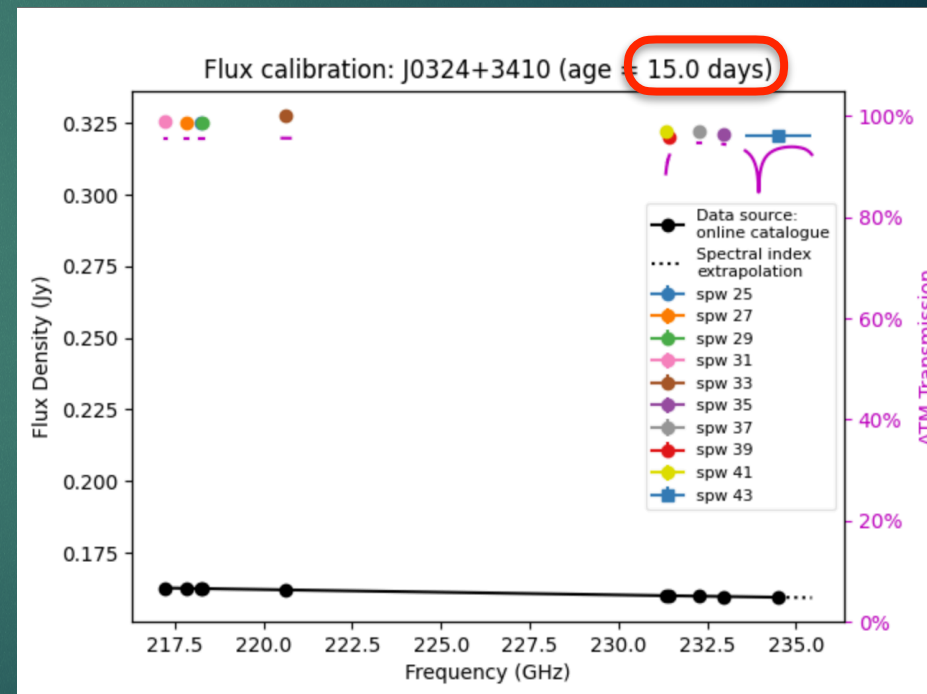
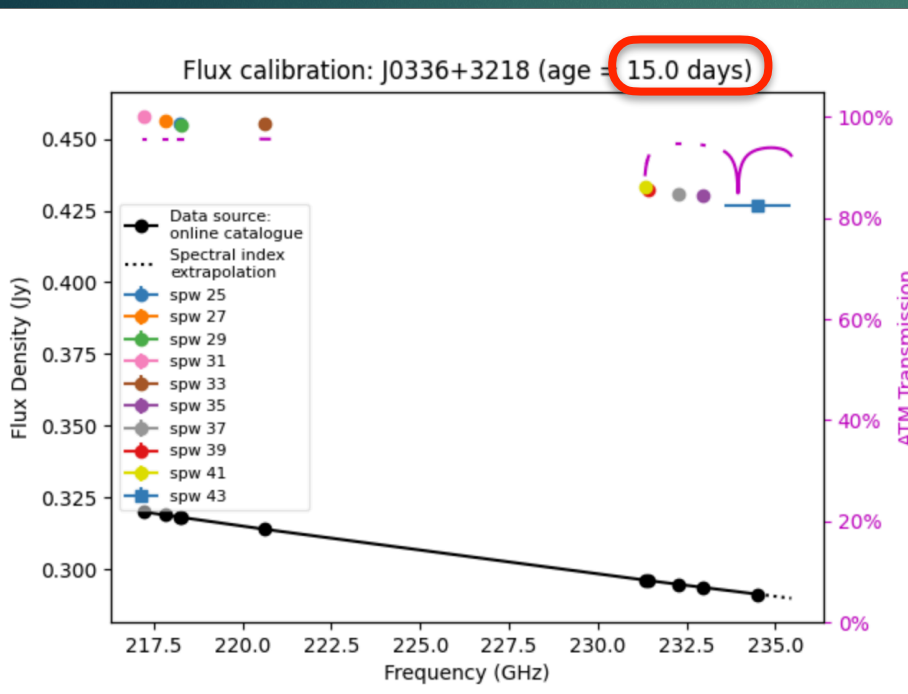
Spectral window



Calibration - Flux model (task 16) (Double check the flux)

Phase calibrator

Check source



Calibration - bandpass (task 13)

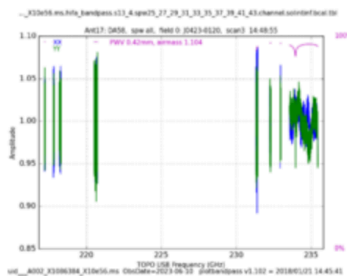
There should not be
glitches or artifacts

Amplitude

uid__A002_X1086384_X10e56.ms

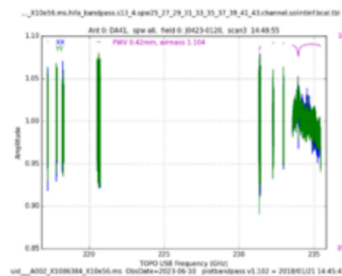
Amplitude vs frequency ([show uid__A002_X1086384_X10e56.ms](#))

The plots below show amplitude vs frequency for the bandpass correction, overlaid for all spectral windows and correlations. Click on the link above to show detailed plots for all antennas, or on the links below to show plots with specific antennas preselected.



Reference antenna (DA58) ([show DA58](#))

Amplitude vs frequency for the reference antenna (DA58).
Click the link above to show detailed plots for DA58.



Typical antenna (DA41) ([show DA41](#))

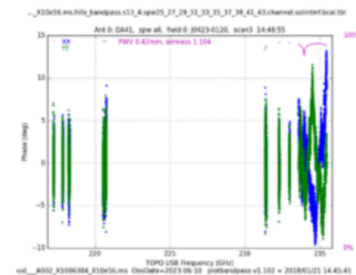
Amplitude vs frequency for a typical antenna (DA41). Click
the link above to show detailed plots for DA41.

NB. random antenna until scores are working

Phase

Phase vs frequency ([show uid__A002_X1086384_X10e56.ms](#))

The plot below shows phase vs frequency for the bandpass correction, overlaid for all spectral windows and correlations. Click on the link above to show phase vs frequency plots for all antennas, or on the link for just the typical antenna.



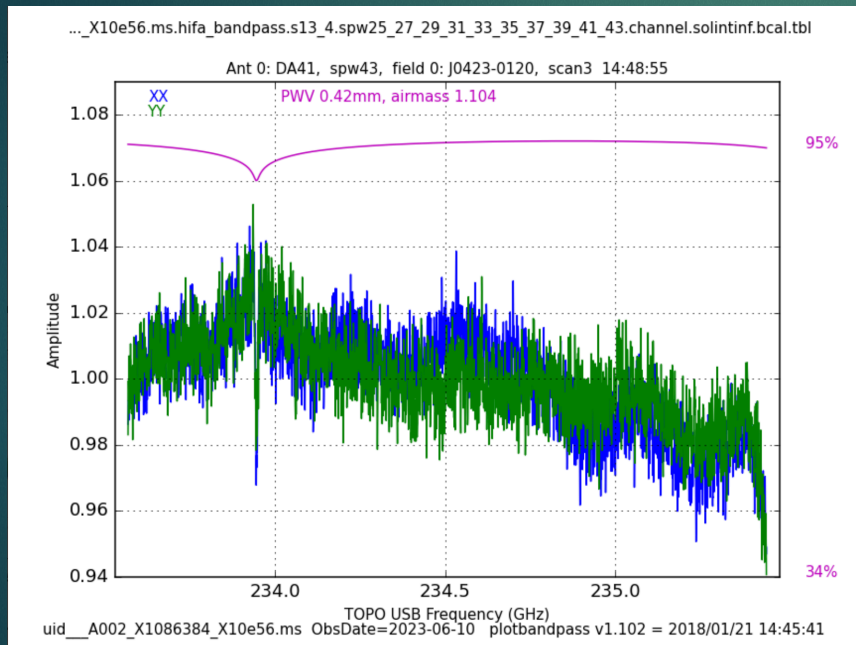
Typical antenna (DA41) ([show DA41](#))

Phase vs frequency for a typical antenna (DA41). Click the
link above to show detailed plots for DA41.

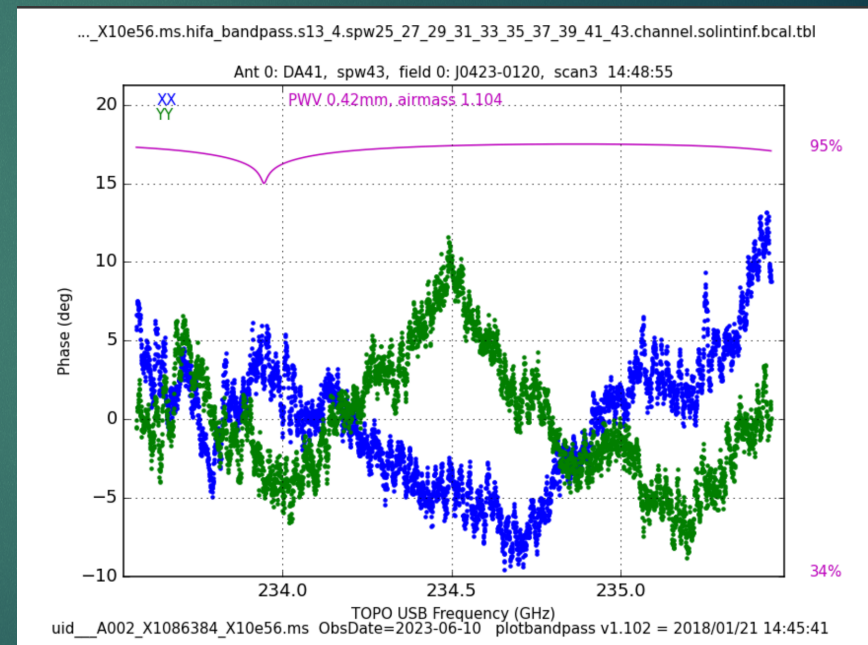
Calibration - bandpass (task 13)

There should not be
glitches or artifacts

Amplitude



Phase



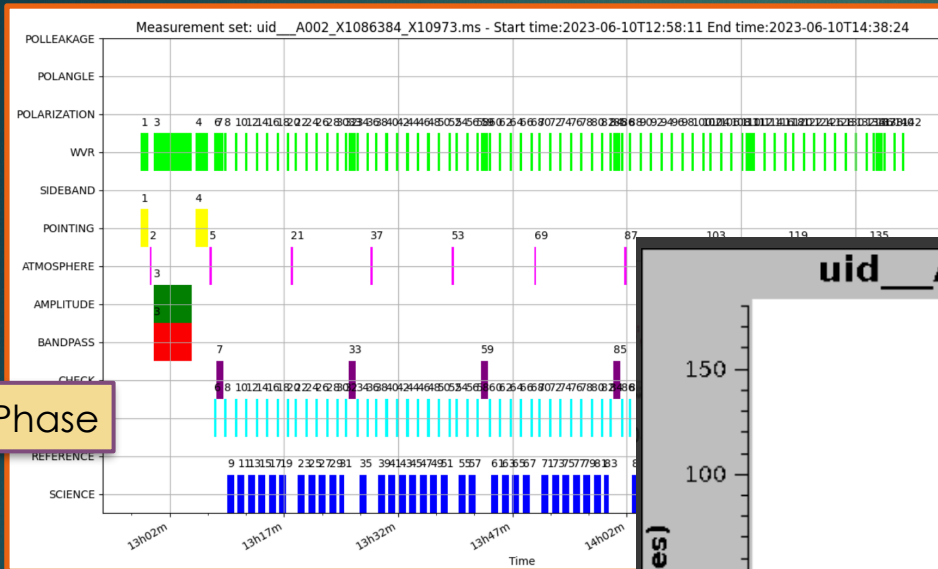
Antenna filter

× DA41

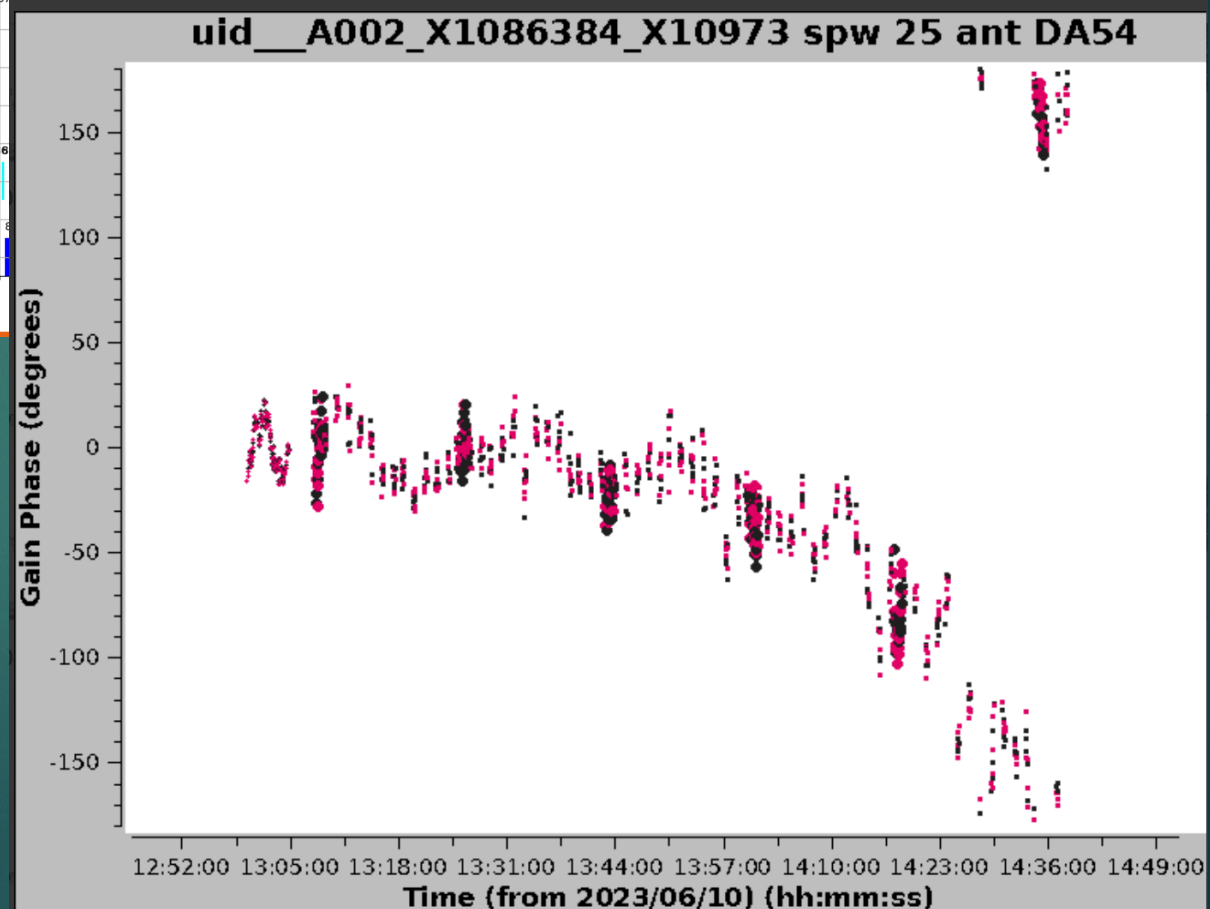
Spectral window filter

× 43

Calibration - gains (phase cal.) (task 17)



Phase



Calibrated data (task 19. hif_applycal) (important)

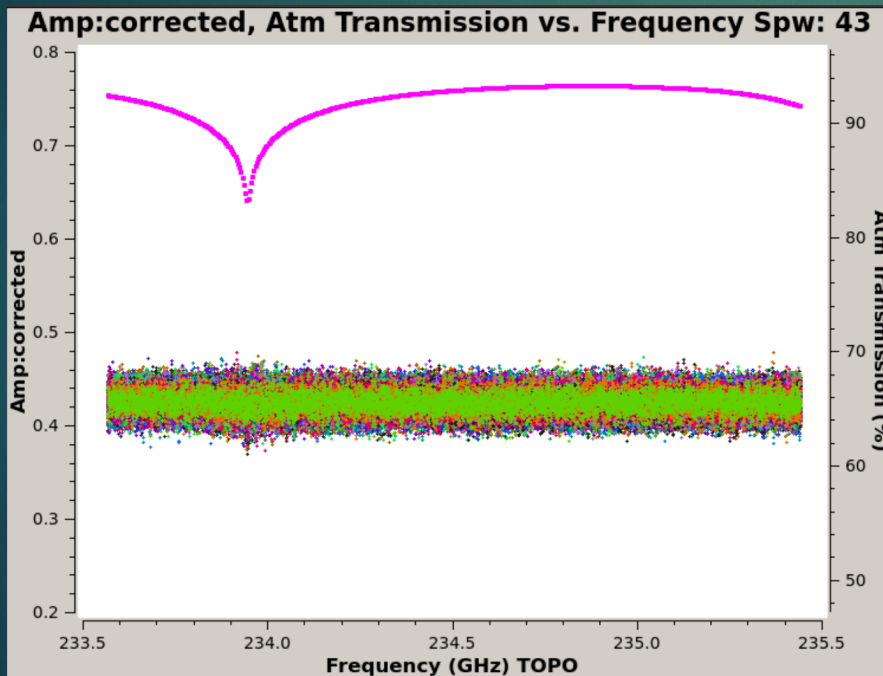
Contents

- Applied calibrations
- Flagged data after calibration application
- Plots
 - Calibrated amplitude vs frequency
 - Calibrated phase vs frequency
 - Calibrated amplitude vs UV distance
 - Calibrated amplitude vs time
 - Calibrated phase vs time
 - (Corrected amplitude / model) vs antenna
 - (Corrected amplitude / model) vs UV distance
 - Science target: calibrated amplitude vs frequency
 - Science target: calibrated amplitude vs UV distance
 - UV coverage

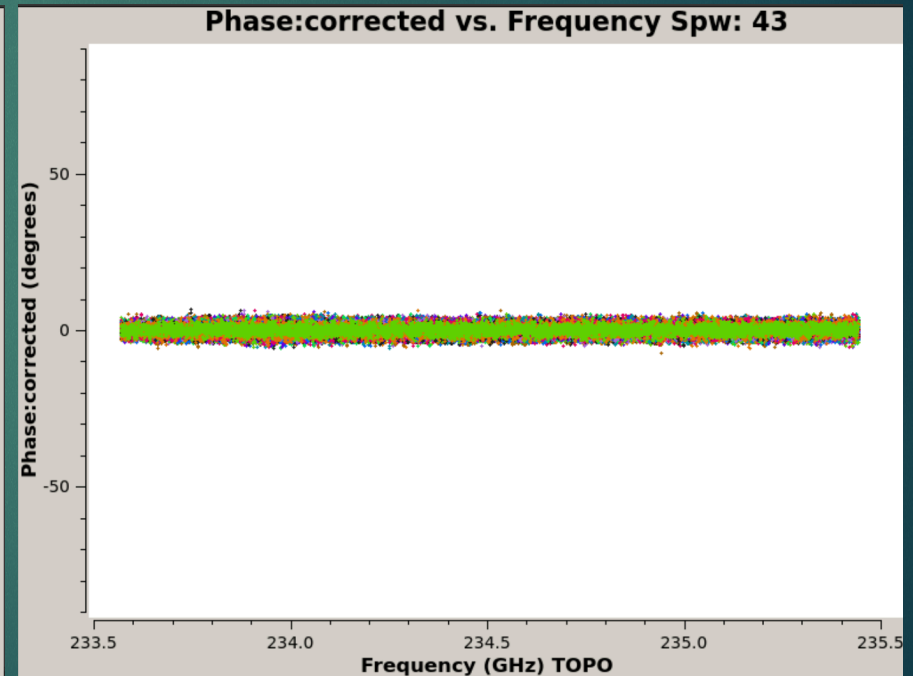
Bandpass after applied solution (task 19)

Phase calibrator after applied solutions (spw43)

Amplitude



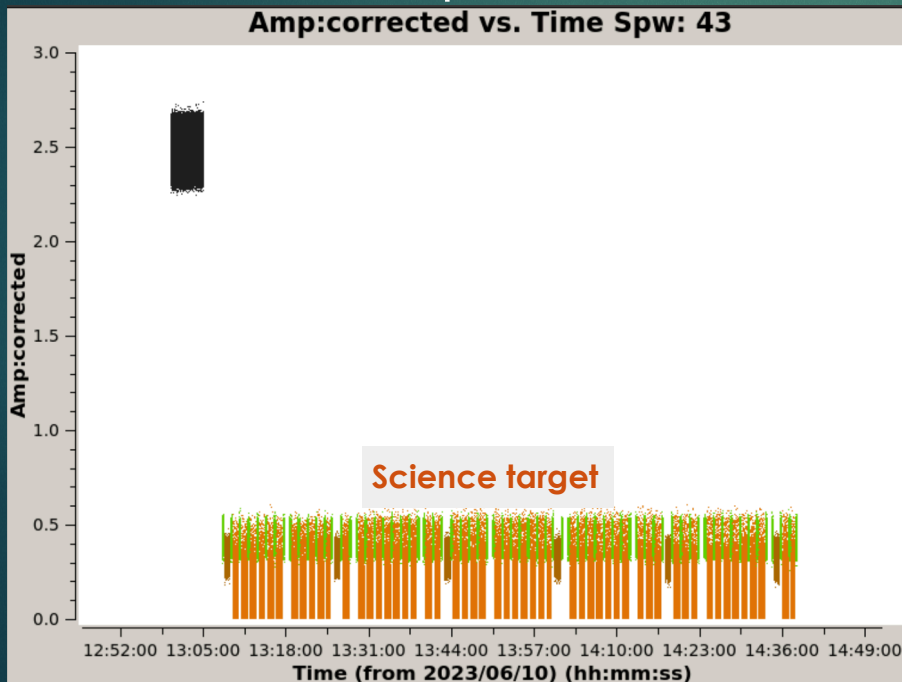
Phase



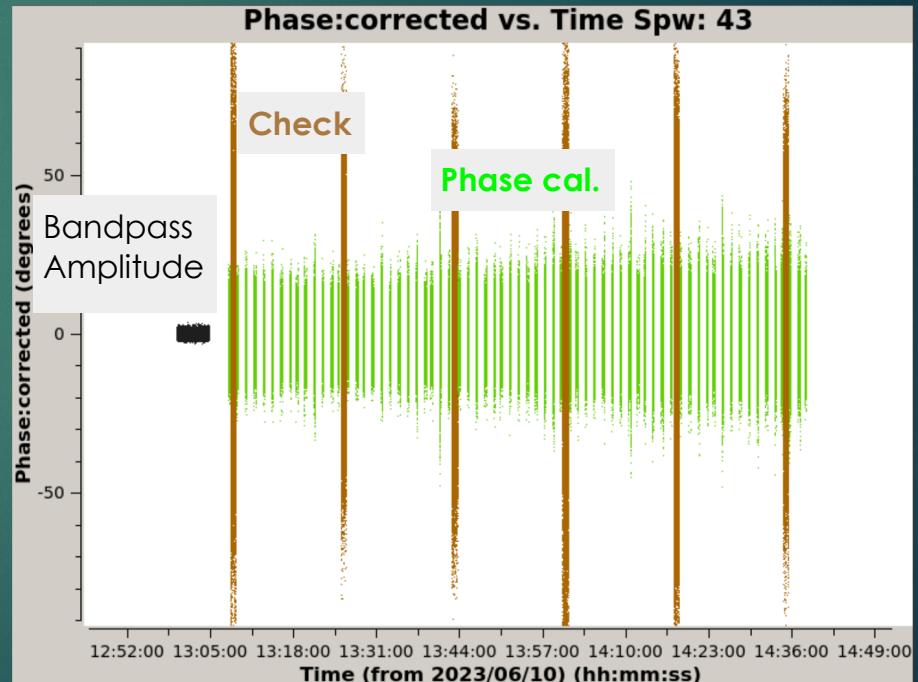
Phase after applied solution (task 19)

Calibrators/sources after applied solutions (spw43)

Amplitude

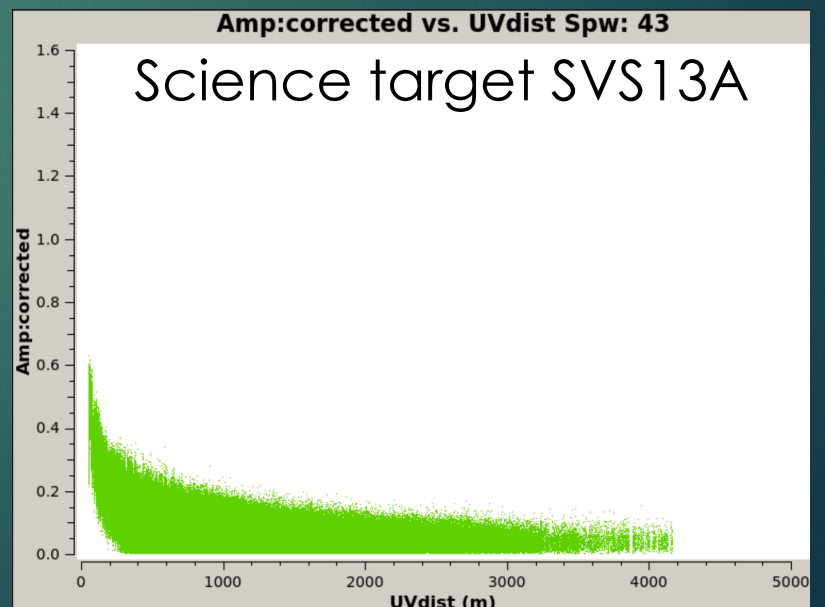
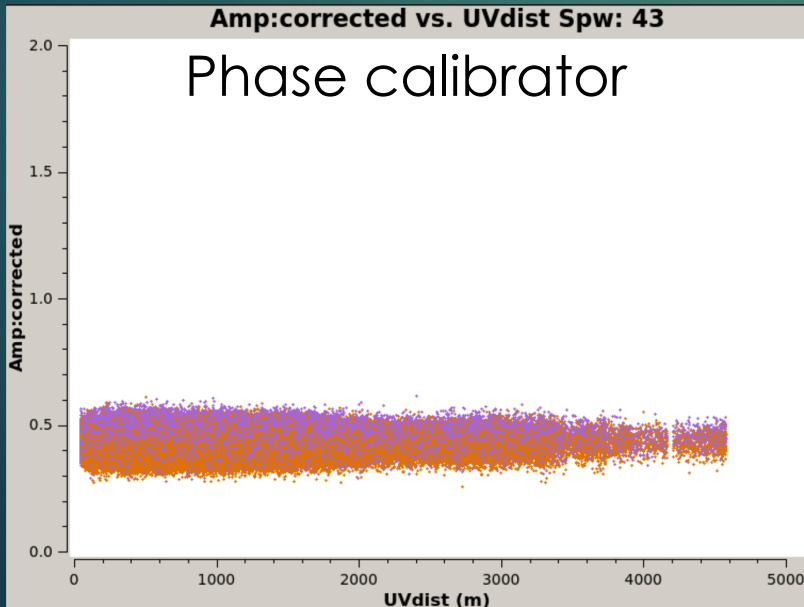
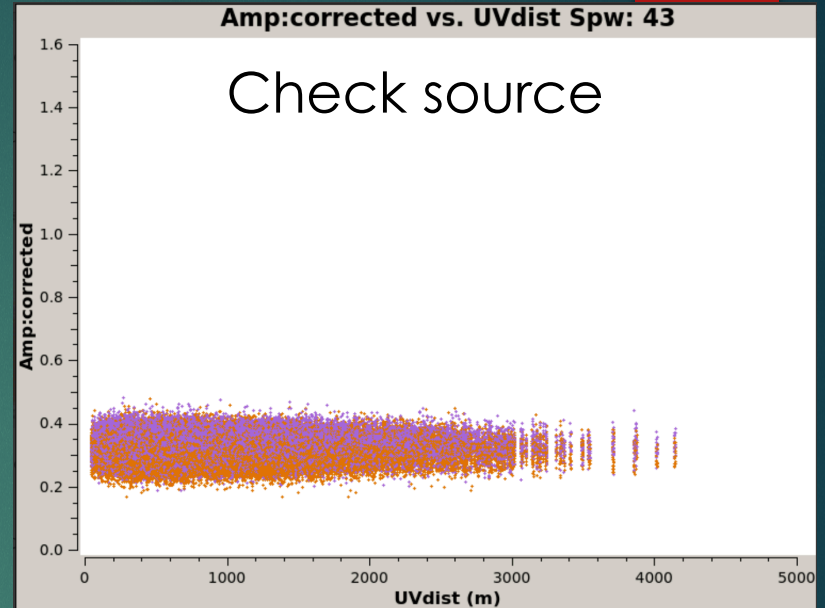
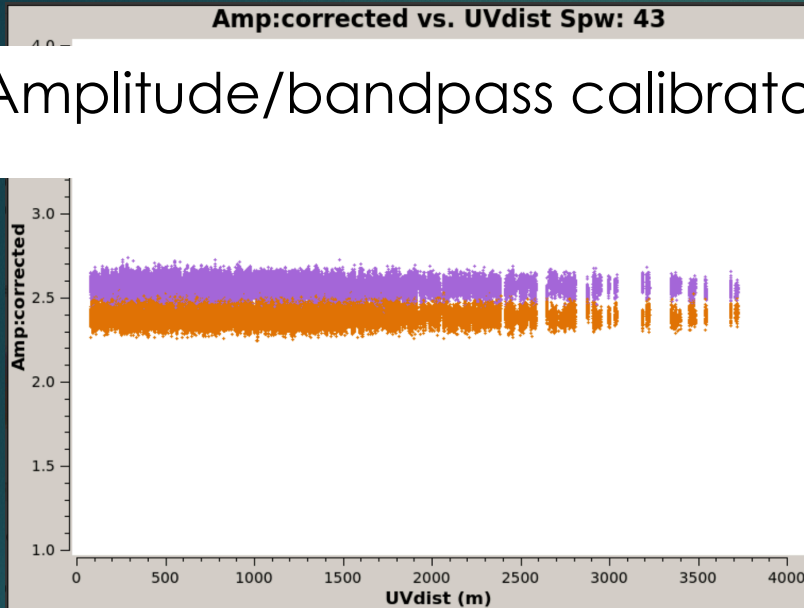


Phase

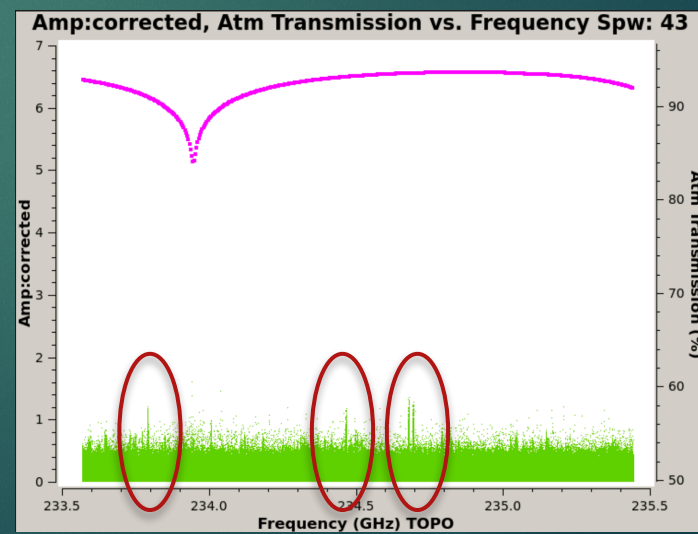
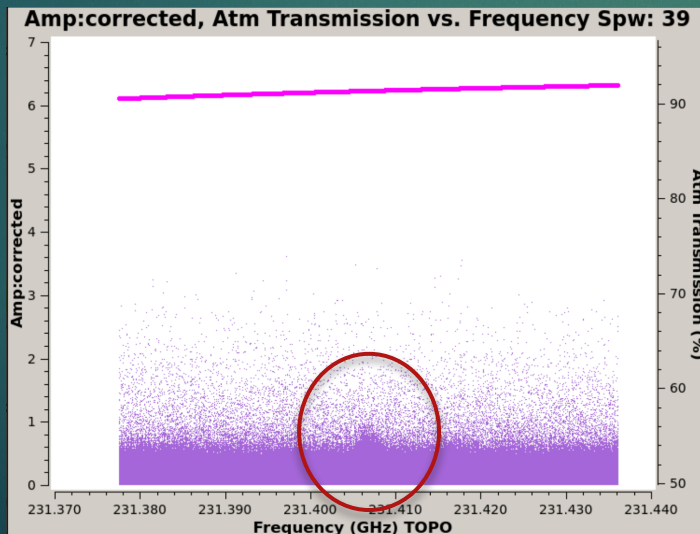
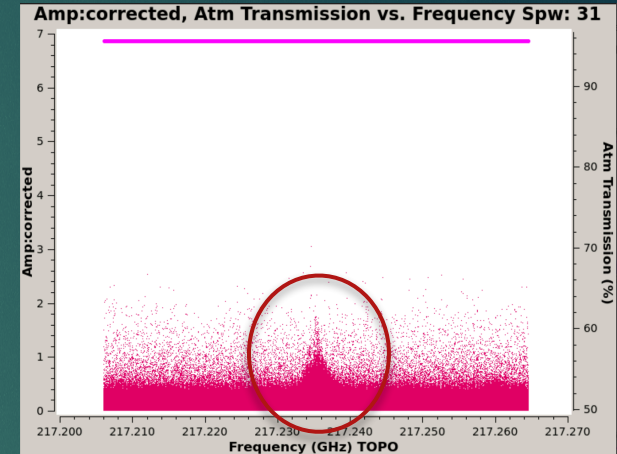
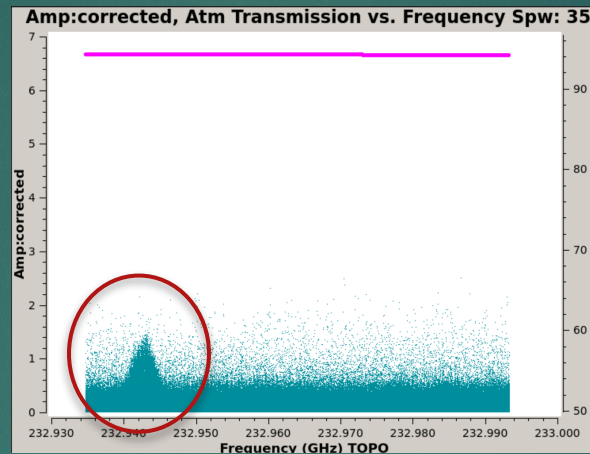
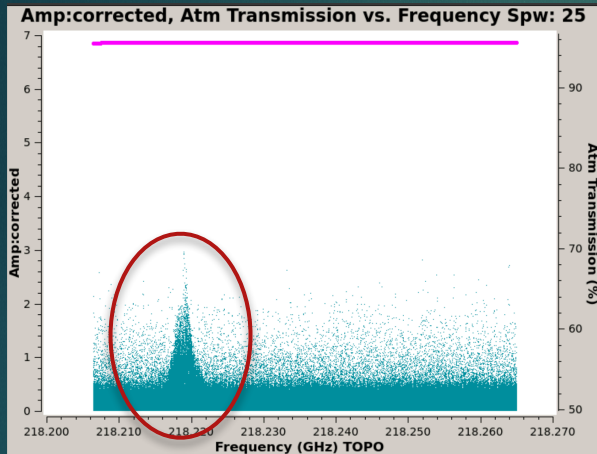


Calibrated **amp** vs **uv-dis** (task 19)

Amplitude/bandpass calibrator



Detection of molecular lines in the science target SVS13A



Notes on PL calibration

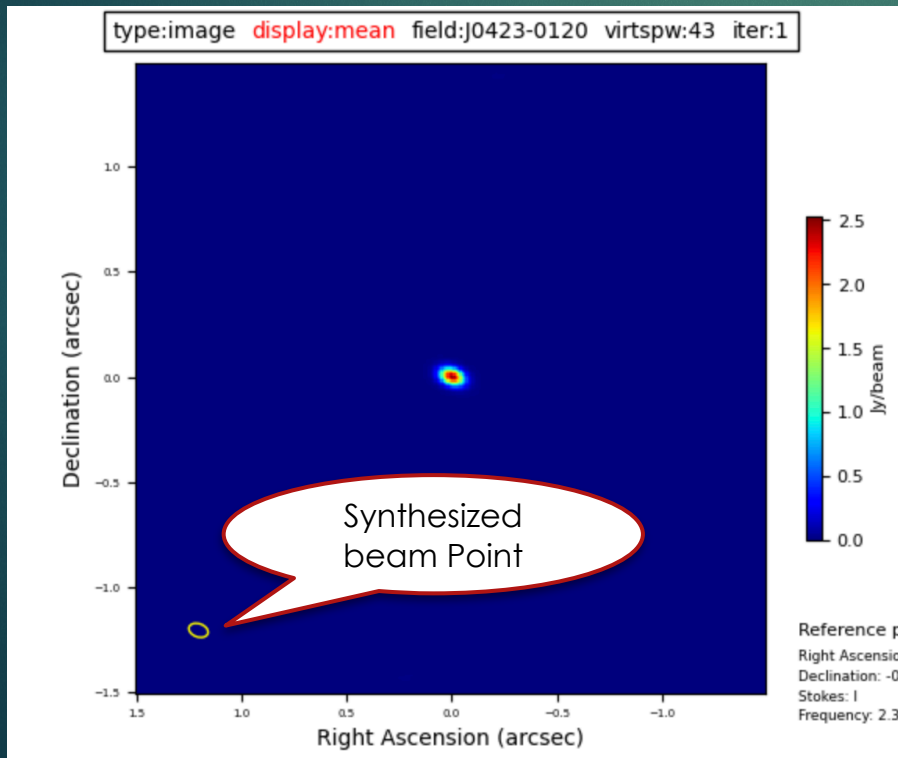
- ▶ Flux results vs ALMA archive
- ▶ No outliers in any kind of gains
- ▶ Diagnostic plots for calibration results
- ▶ Sample images for phase calibrator

Calibrator images (task 21)

- ▶ Check flux peak per spw (image domain) if fluxscale section looks problematic

(Task 20)

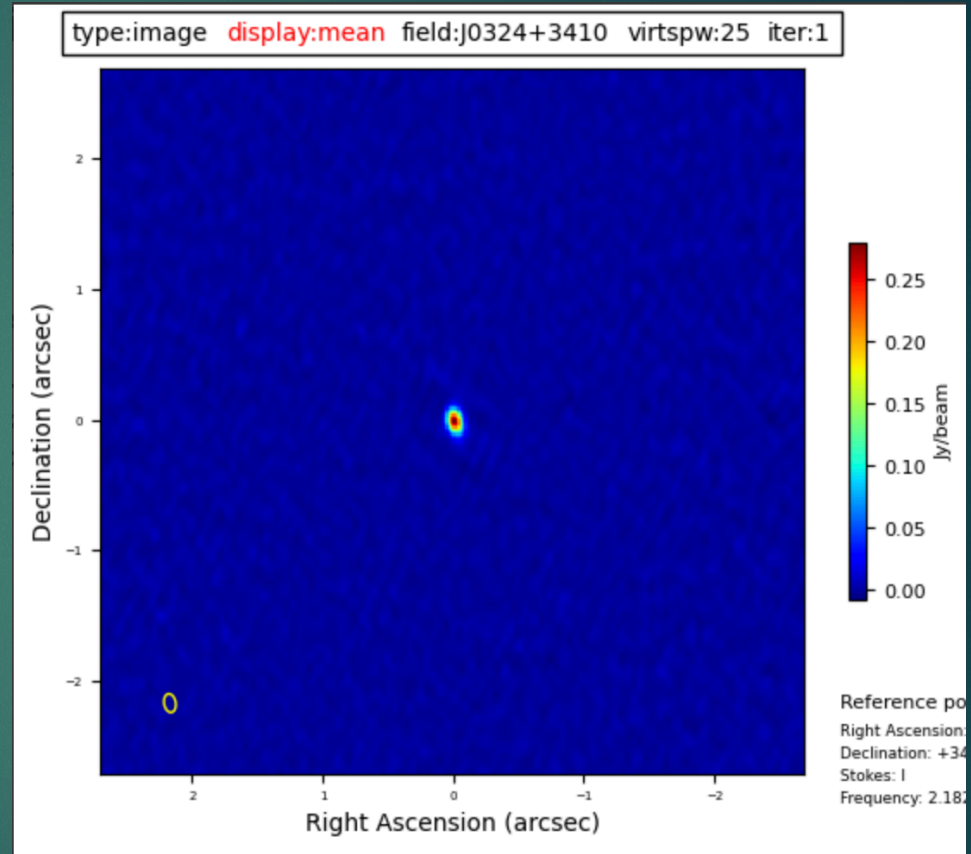
field	intent	spw	phasecenter	cell	imsize
J0423-0120	BANDPASS	43	ICRS 04:23:15.8007 -001.20.33.065	['0.01arcsec']	[300, 300]



centre frequency of	234.5083GHz (LSRK)
image	The angular resolution
beam	0.0945 x 0.0630 arcsec
beam p.a.	70.6deg
final theoretical sensitivity	40 uJy/beam
cleaning threshold	1.9 mJy/beam Dirty DR: 6.4e+04 DR correction: 23
clean residual peak / scaled MAD	-5.44
non-pbcor image RMS	0.86 mJy/beam
pbcor image max / min	2.54 / -0.00375 Jy/beam
fractional bandwidth	0.8% / 1
/ nterms	This image is integrated along frequency
aggregate bandwidth	1.88 GHz (LSRK)

Does the check source look like a point source (Task 23)

- ▶ Fit flux should be comparable to the image
- ▶ Fit source position consistent with original image



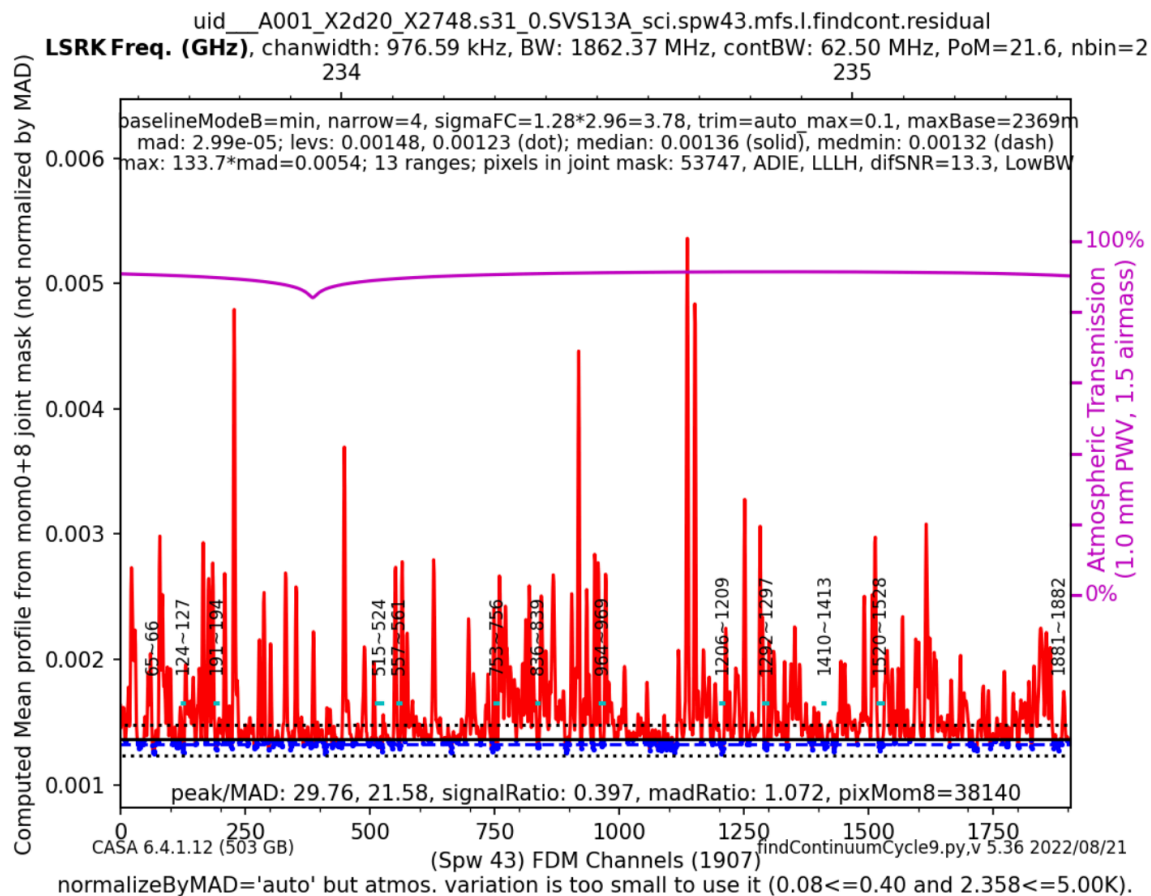
EB	Field	Virtual SPW	Bandwidth (GHz)	Position offset (mas)	Position offset (synth beam)	Fitted Flux Density (mJy)	Image S/N	Fitted [Peak Intensity / Flux Density] Ratio	gfluxscale mean visibility	gfluxscale S/N	[Fitted / gfluxscale] Flux Density Ratio
uid__A002_X1086384_X10973	J0324+3410	25	0.05859	12.60 +/- 0.51	0.11 +/- 0.005	304 +/- 3	165.07	0.93	324.96 +/- 0.72	452.91	0.94

Pipeline imaging weblog

Continuum find (task 31) (to divide continuum and lines emission)

- ▶ It can be a hard task given the high-sensitivity of ALMA

SPW43



PL will produce following images (tasks 34-38)

- ▶ continuum images per spw (34)
- ▶ One aggregate continuum image (all spw) (35-36)
- ▶ Line cubes per spw (native resolution) (37-38)

34. hif_makeimages (mfs)

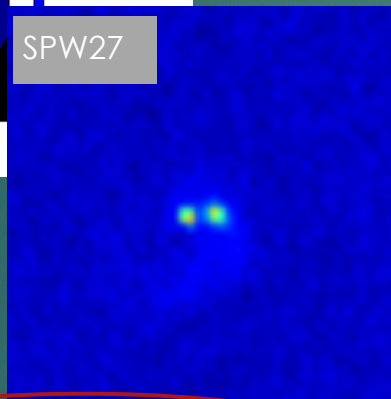
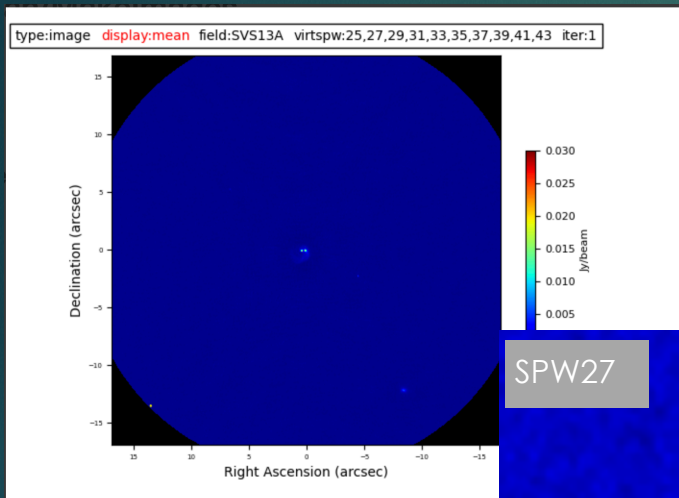
35. hif_makeimlist (cont)

36. hif_makeimages (cont)

37. hif_makeimlist (cube)

38. hif_makeimages (cube)

A quick look for the continuum images (integrated/aggregated)



non-pbcor image RMS	0.4 mJy/beam
pbcor image max / min	29.4 / -3.42 mJy/beam
fractional bandwidth / nterms	0.015% / 1
aggregate bandwidth	0.00257 GHz (LSRK)

RMS	0.1 mJy/beam
pbcor image max / min	31.8 / -1.04 mJy/beam
fractional bandwidth / nterms	0.76% / 1
aggregate bandwidth	0.0625 GHz (LSRK)

RMS	66 uJy/beam
pbcor image max / min	30 / -0.627 mJy/beam
fractional bandwidth / nterms	8% / 1
aggregate bandwidth	0.154 GHz (LSRK)

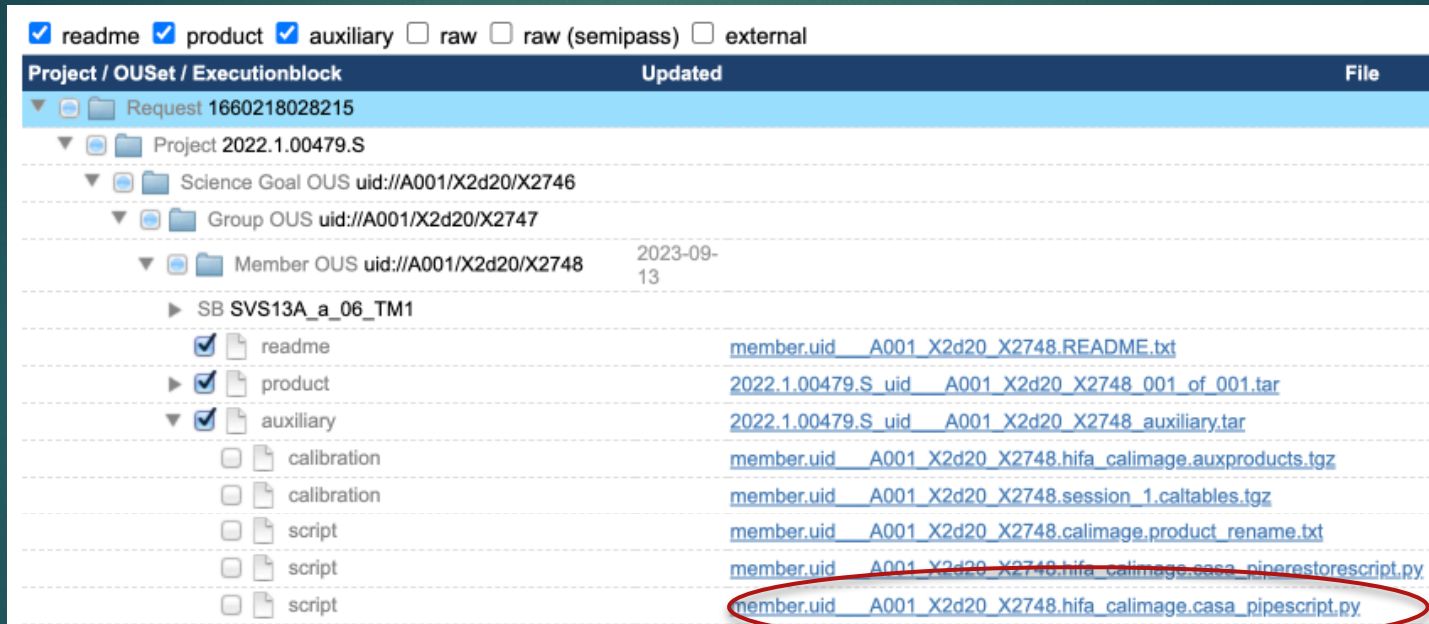


Re-running Pipeline calibration and imaging

Re-launching PL imaging

- ▶ Re-run pipeline

- ▶ https://almascience.nrao.edu/processing/alma_pipeline_user_s_guide_for_release_2024-1.pdf (PL user guide)



Project / OUSet / Executionblock	Updated	File
Request 1660218028215		
Project 2022.1.00479.S		
Science Goal OUS uid://A001/X2d20/X2746		
Group OUS uid://A001/X2d20/X2747		
Member OUS uid://A001/X2d20/X2748	2023-09-13	
SB SVS13A_a_06_TM1		
<input checked="" type="checkbox"/> readme		member.uid_A001_X2d20_X2748.README.txt
<input type="checkbox"/> product		2022.1.00479.S_uid_A001_X2d20_X2748_001_of_001.tar
<input checked="" type="checkbox"/> auxiliary		2022.1.00479.S_uid_A001_X2d20_X2748_auxiliary.tar
<input type="checkbox"/> calibration		member.uid_A001_X2d20_X2748.hifa_calimage_auxproducts.tgz
<input type="checkbox"/> calibration		member.uid_A001_X2d20_X2748.session_1.caltables.tgz
<input type="checkbox"/> script		member.uid_A001_X2d20_X2748.calimage.product_rename.txt
<input type="checkbox"/> script		member.uid_A001_X2d20_X2748.hifa_calimage.casa_piperestorescript.py
<input type="checkbox"/> script		member.uid_A001_X2d20_X2748.hifa_calimage.casa_pipescript.py

- ▶ Re-run pipeline imaging

- ▶ https://casaguides.nrao.edu/index.php/ALMA_Imaging_Pipeline_Reprocessing

Final notes

- ▶ Check on flux calibration
- ▶ How images were produced
- ▶ Do not trust blindly imaging results

- ▶ Ask the ARC or CS technical aspects to speed up your investigation

Thanks for your attention