The VLA Calibration Pipeline

Claire Chandler, NRAO

Pipeline Overview

- With the start of Jansky VLA Full Operations (January 2013), we started a new operational model:
  - Deliver automatically-flagged and calibrated visibility data
  - You will check the calibration, do additional flagging if needed, then self-calibrate and image visibility data to meet science goals, using resources at home institution or NRAO computing resources
- Automated pipeline should run correctly on all "standard" continuum Stokes I science SBs, may work for other set-ups as well
- Current versions available:
  - CASA integrated pipeline is compatible with ALMA pipeline infrastructure, improved diagnostics in weblog, used as real-time pipeline since Sep 2015
  - "scripted" pipeline is a collection of python scripts that use CASA tasks wherever possible, but also uses toolkit calls; readable and easy to modify

Pipeline Operation

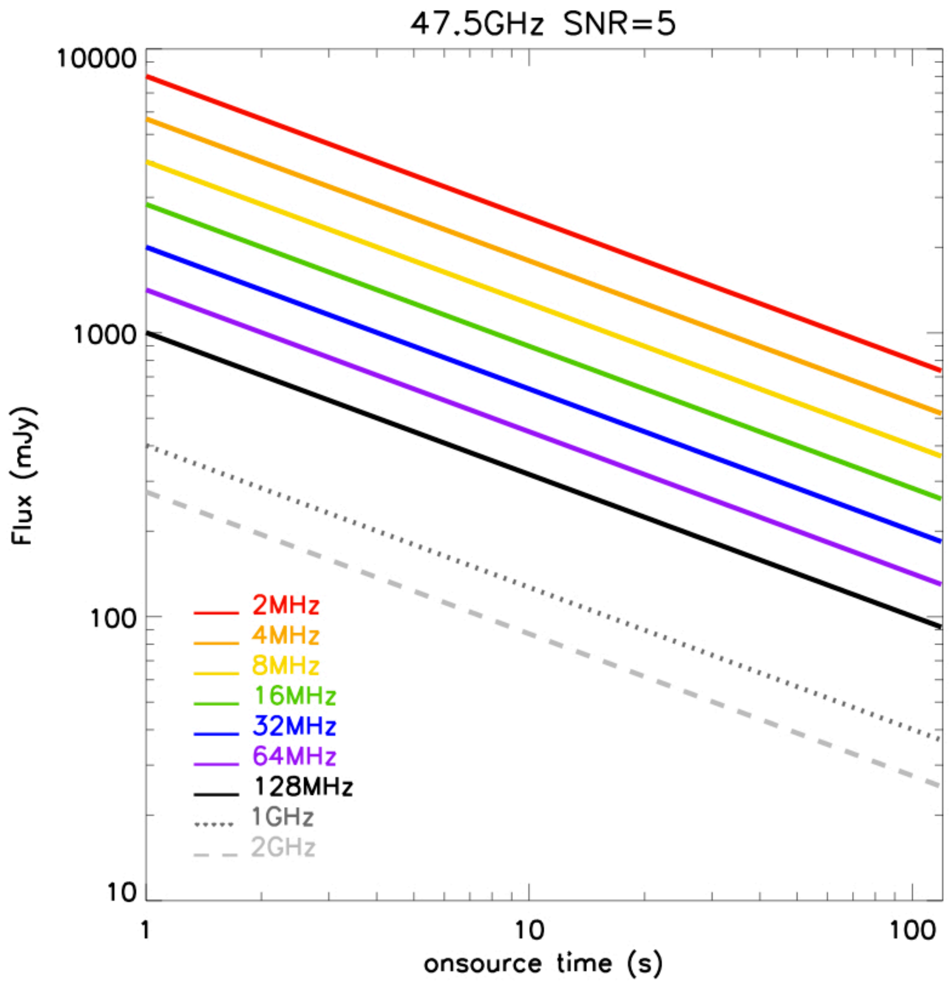
- Real-time pipeline:
  - Minimal human intervention
    - Pipeline is run automatically on *every* science SB as it completes (not just “continuum”)
  - Pipeline output undergoes basic quality assurance checks by NRAO staff, and detailed checks upon request; reports generated are archived as pipeline products
- At your home institution:
  - Instructions for installation and operation of the VLA CASA Calibration Pipeline are available at http://go.nrao.edu/vla-pipe
    - Uses CASA 5.1.1, similar to current real-time pipeline
    - See the VLA CASA pipeline guide at http://go.nrao.edu/vla-casa-tut
- Scripted pipelines for CASA versions through 5.0.0 also available
  - Provides more flexibility in how to use the pipeline, options suitable for spectral line datasets, mixed correlator set-ups, multi-band observations, etc.

Pipeline Requirements

- Will the pipeline work for you?
  - The pipeline successfully completes on >90% of all science SBs observed on the VLA; whether the output can be used for science depends on the science goal, and whether the observation was correctly set up
    - Pipeline includes Hanning smoothing, RFI flagging, and weight calculations that may not be appropriate for spectral line projects (but can modify scripted pipeline)
    - No polarization calibration in default pipeline yet (but see later…)
    - Will probably work well for data taken since May 2012, may work for earlier EVLA data, likely that extra flagging may be needed in these cases
- "Standard" continuum Stokes I science SB means:
  - 128 MHz spws, but may work on other set-ups as well
    - Can work for narrower BWs, depends on the strength of the calibrators
    - Heuristics currently make some assumptions about the strength of the calibrators, in particular, the delay calibrator
  - Contains correctly labeled and complete scan intents
    - And also that the observation has been set up correctly!

Pipeline Requirements

- Calibrator strength:
  - Conservative limit on strength of BP and complex gain calibrators can be derived from requirement for initial gain calibration to work at high end of Q-band
  - Heuristic for delay calibration currently requires the SNR=3 limit on initial gain calibration *per integration*



Pipeline Requirements

- Correct observation set-up
  - Independent of whether you want to run the pipeline!
  - Remember: simple observing set-ups are always easier to calibrate
  - Do not skimp on calibration to spend more time on your target – you may end up not being able to calibrate the target data at all
    - Spending 3 minutes pointing could buy you more sensitivity than doubling the time on your target
- Scan intents
  - The pipeline relies entirely on correct *scan intents* to be defined in each SB
  - In order for the pipeline to run successfully on an SB it must contain, *at minimum*, scans with the following intents:
    - A flux density calibrator scan that observes one of the primary calibrators (3C48, 3C138, 3C147, or 3C286) – this will also be used as the delay and bandpass calibrator if no bandpass or delay calibrator is defined
    - Complex gain calibrator scans

(Real-Time) Heuristics (I)

- Assuming requirements are met, the pipeline:
  - Loads the data
  - Hanning smooths*
  - Retrieves information about the observing set-up from the data
  - Applies deterministic flags (online flags, shadowed data, end channels of sub-bands, etc.)
  - Identifies primary calibrators and loads models
  - Derives all prior calibrations (antenna position corrections, gain curves, atmospheric opacity, requantizer gains)
  - Iteratively determines initial delay and bandpass solutions, including running RFLAG (RFI flagging algorithm), and identifying other system (deformatter) problems

*May want to modify inputs and/or omit entirely for spectral line reductions, depending on level of Gibbs ringing due to RFI or strong emission lines

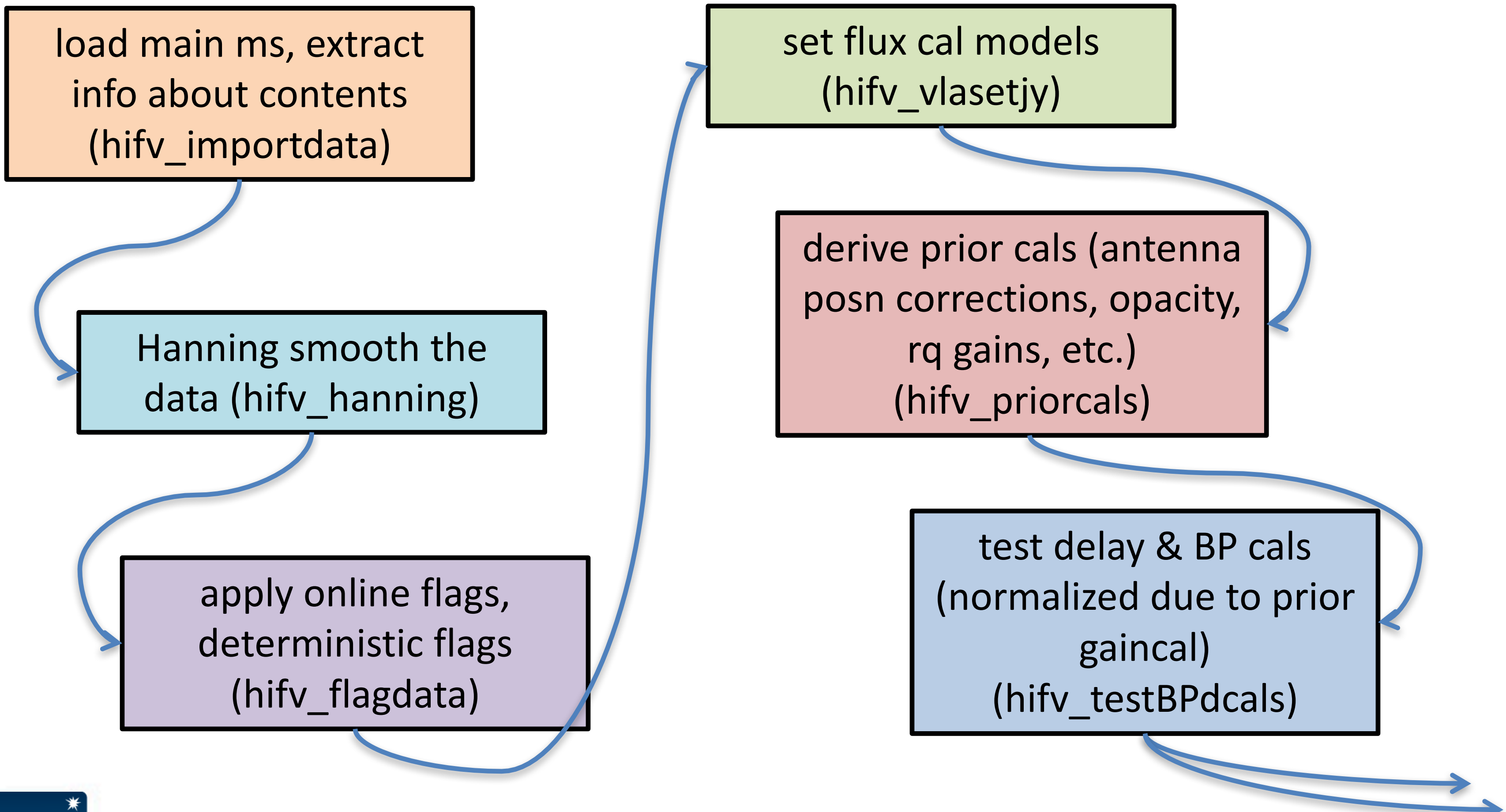
(Real-Time) Heuristics (II)

- Heuristics (cont.): the pipeline:
  - Derives initial gain solutions, does flux density bootstrapping and derives spectral index of all calibrators
  - Derives final delay, bandpass, and gain calibrations
  - Applies all calibrations to the MS
  - Runs RFLAG algorithm on all fields, including target**
  - Runs statwt to derive proper relative weights per antenna/spw**

**May want to modify inputs and/or omit entirely for spectral line reductions

Flow chart (CASA pipeline)

- Each major step is executed as a separate pipeline task:

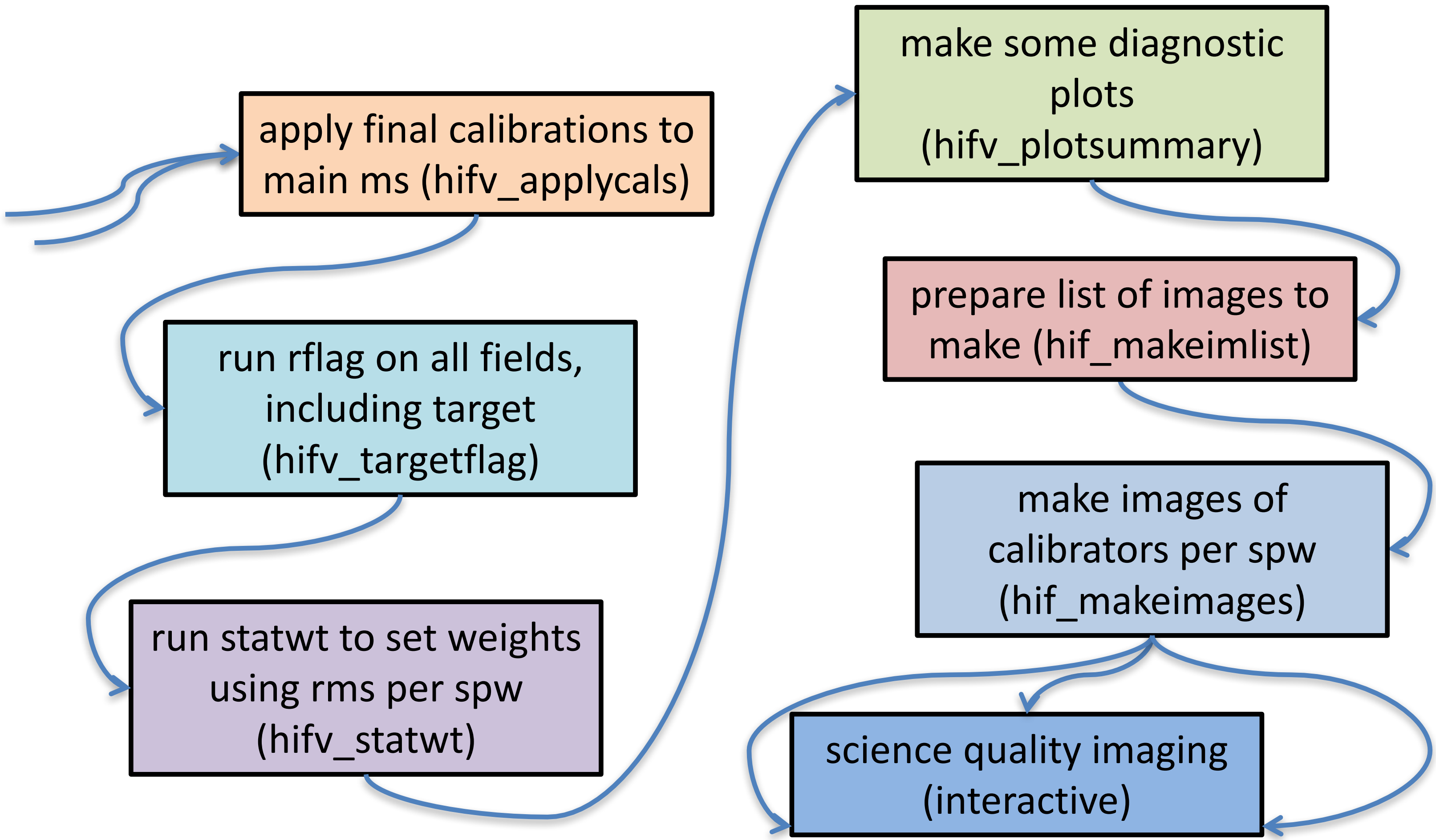


Flow chart

1. flag bad deformatters/spws (hifv_flagbaddef)
2. run rflag on calibrated delay & BP cals (hifv_checkflag)
3. "semiFinal" delay & BP cals (not normalized, sp. index of BPcal not yet determined) (hifv_semiFinalBPdcals, hifv_checkflag, hifv_semiFinalBPdcals)
4. split out calibrators with spectral averaging into calibrators.ms, do a test gaincal to determine short and long solints (hifv_solint)
5. make amp gain table for flux density bootstrapping, and do flux density bootstrapping; includes deriving sp. index of calibrators and re-inserting into main ms (hifv_fluxboot)
6. make final cal tables (delay, BP, amp, phase) – includes redoing split, fluxboot, etc. (hifv_finalcals)

NRAO

Flow chart


apply final calibrations to main ms (hifv_applycals)
run rflag on all fields, including target (hifv_targetflag)
run statwt to set weights using rms per spw (hifv_statwt)
make some diagnostic plots (hifv_plotsummary)
prepare list of images to make (hif_makeimlist)
make images of calibrators per spw (hif_makeimages)
science quality imaging (interactive)

Pipeline Weblog

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file:///Users/cchandle/talks/2017/DRWkshp/pipeline-20171018T162015/html/t1-1.html

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Observation Overview

Project	uid://evla/pdb/30673845
Principal Investigator	Dr. Tim Bastian
Observation Start	2015-08-02 17:16:40 UTC
Observation End	2015-08-02 17:52:28 UTC

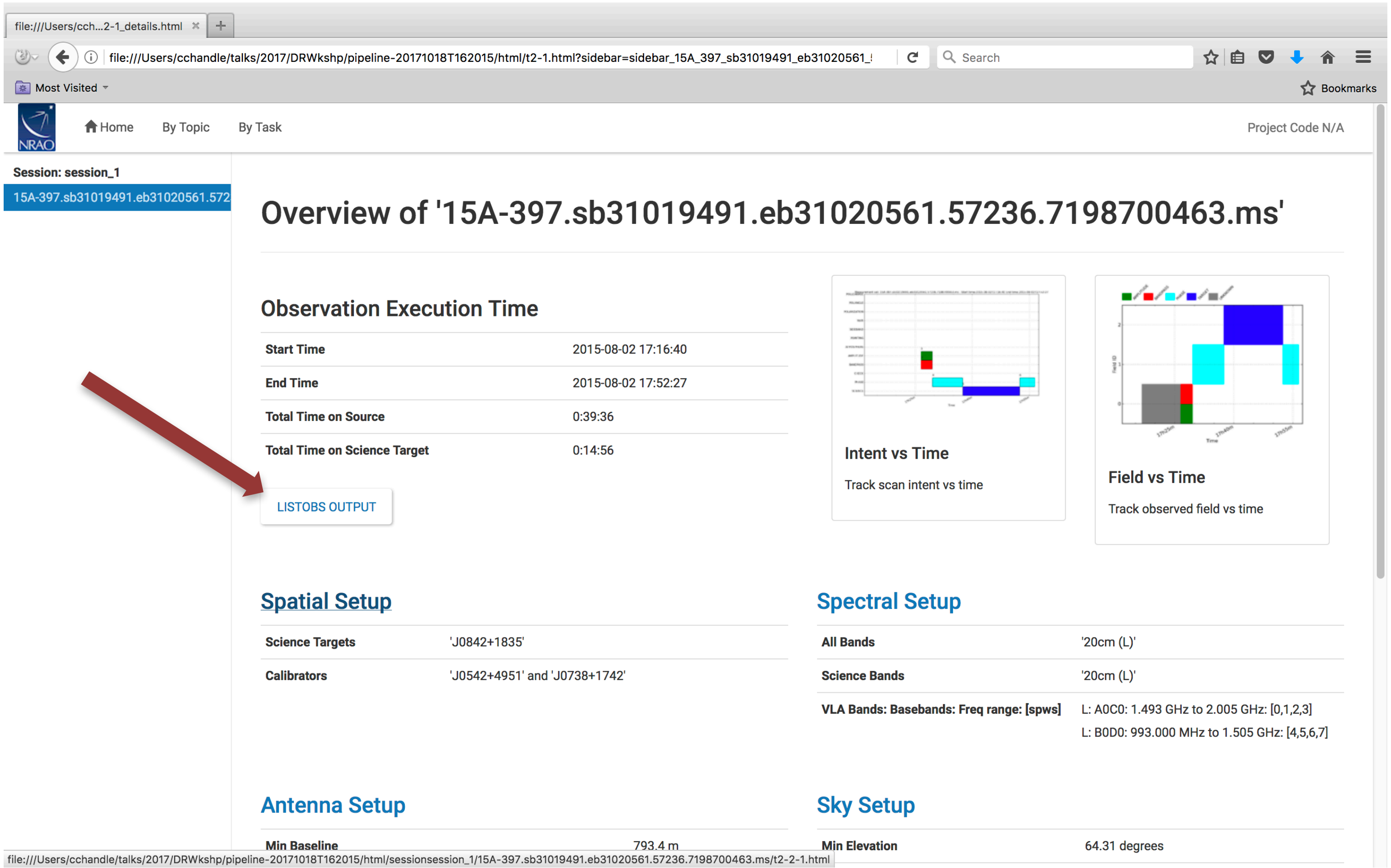
Pipeline Summary

Pipeline Version	40896 (Pipeline-CASA51-P2-B)
CASA Version	5.1.1-5 r40000
Pipeline Start	2017-10-18 16:20:16 UTC
Execution Duration	1:52:33

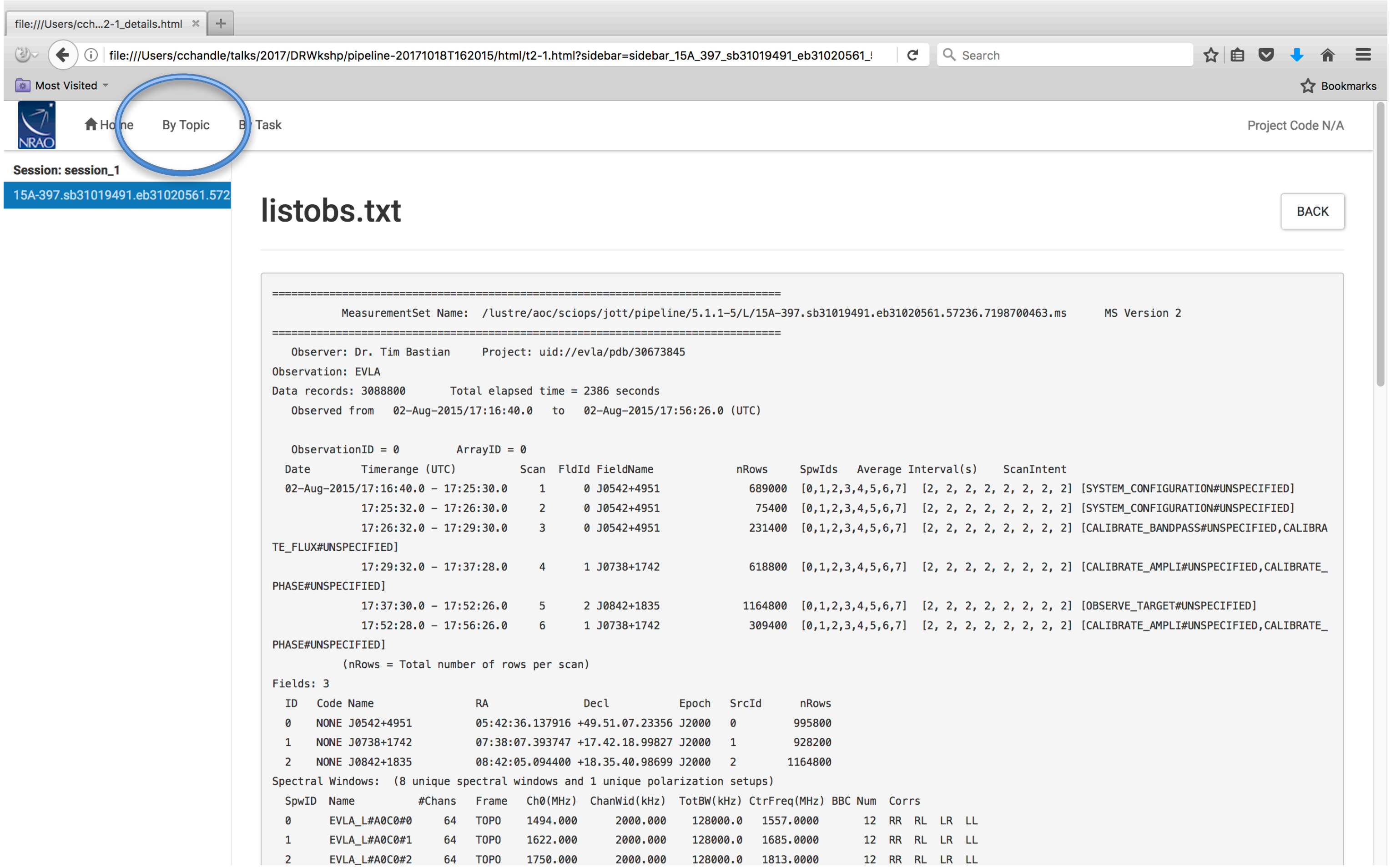
Observation Summary

			Time (UTC)			Baseline Length			
Measurement Set	**Receivers**	**Num Antennas**	**Start**	**End**	**On Source**	**Min**	**Max**	**RMS**	**Size**
Scheduling Block ID: uid://evla/pdbsb/31019491									
Session: session_1									
15A-397.sb31019491.eb31020561.57236.7198700463.ms	20cm (L)	26	2015-08-02 17:16:40	2015-08-02 17:52:27	0:14:56	793.4 m	34.4 km	14.8 km	6.2 GB

Pipeline Weblog

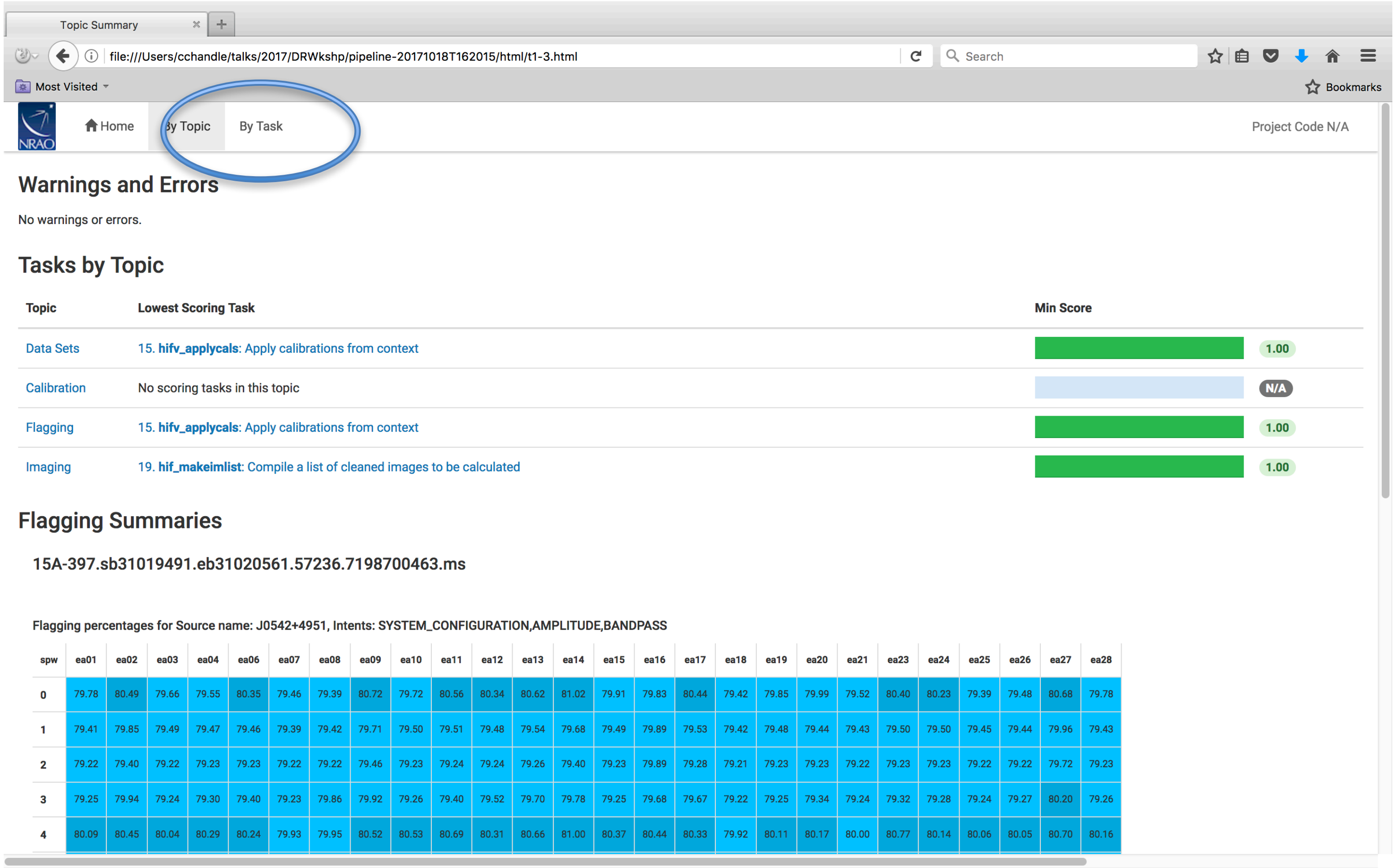


Pipeline Weblog



NRAO

Pipeline Weblog


Topic Summary

file:///Users/cchandle/talks/2017/DRWkshp/pipeline-20171018T162015/html/t1-3.html

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By Topic

By Task

Project Code N/A

Warnings and Errors

No warnings or errors.

Tasks by Topic

Topic	Lowest Scoring Task	Min Score
Data Sets	15. **hifv_applycals**: Apply calibrations from context	1.00
Calibration	No scoring tasks in this topic	N/A
Flagging	15. **hifv_applycals**: Apply calibrations from context	1.00
Imaging	19. **hif_makeimlist**: Compile a list of cleaned images to be calculated	1.00

Flagging Summaries

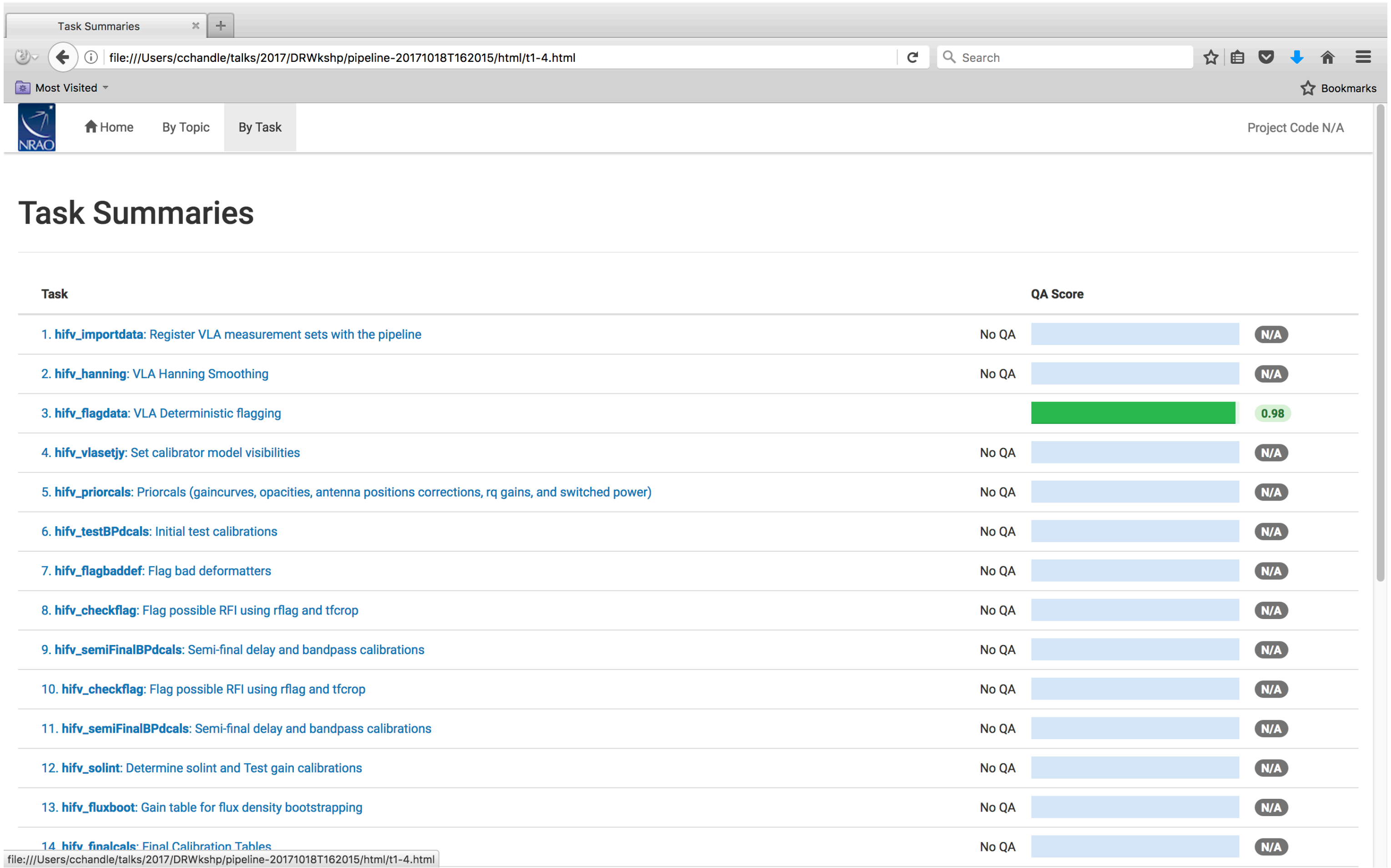
15A-397.sb31019491.eb31020561.57236.7198700463.ms

Flagging percentages for Source name: J0542+4951, Intents: SYSTEM_CONFIGURATION,AMPLITUDE,BANDPASS

spw	ea01	ea02	ea03	ea04	ea06	ea07	ea08	ea09	ea10	ea11	ea12	ea13	ea14
0	79.78	80.49	79.66	79.55	80.35	79.46	79.39	80.72	79.72	80.56	80.34	80.62	81.02
1	79.41	79.85	79.49	79.47	79.46	79.39	79.42	79.71	79.50	79.51	79.48	79.54	79.68
2	79.22	79.40	79.22	79.23	79.23	79.22	79.22	79.46	79.23	79.24	79.24	79.26	79.40
3	79.25	79.94	79.24	79.30	79.40	79.23	79.86	79.92	79.26	79.40	79.52	79.70	79.78
4	80.09	80.45	80.04	80.29	80.24	79.93	79.95	80.52	80.53	80.69	80.31	80.66	81.00

spw	ea15	ea16	ea17	ea18	ea19	ea20	ea21	ea23	ea24	ea25	ea26	ea27	ea28
0	79.91	79.83	80.44	79.42	79.85	79.99	79.52	80.40	80.23	79.39	79.48	80.68	79.78
1	79.49	79.89	79.53	79.42	79.48	79.44	79.43	79.50	79.50	79.45	79.44	79.96	79.43
2	79.23	79.89	79.28	79.21	79.23	79.23	79.22	79.23	79.23	79.22	79.22	79.72	79.23
3	79.25	79.68	79.67	79.22	79.25	79.34	79.24	79.32	79.28	79.24	79.27	80.20	79.26
4	80.37	80.44	80.33	79.92	80.11	80.17	80.00	80.77	80.14	80.06	80.05	80.70	80.16

Pipeline Weblog



Task Summaries

file:///Users/cchandle/talks/2017/DRWkshp/pipeline-20171018T162015/html/t1-4.html

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Task Summaries

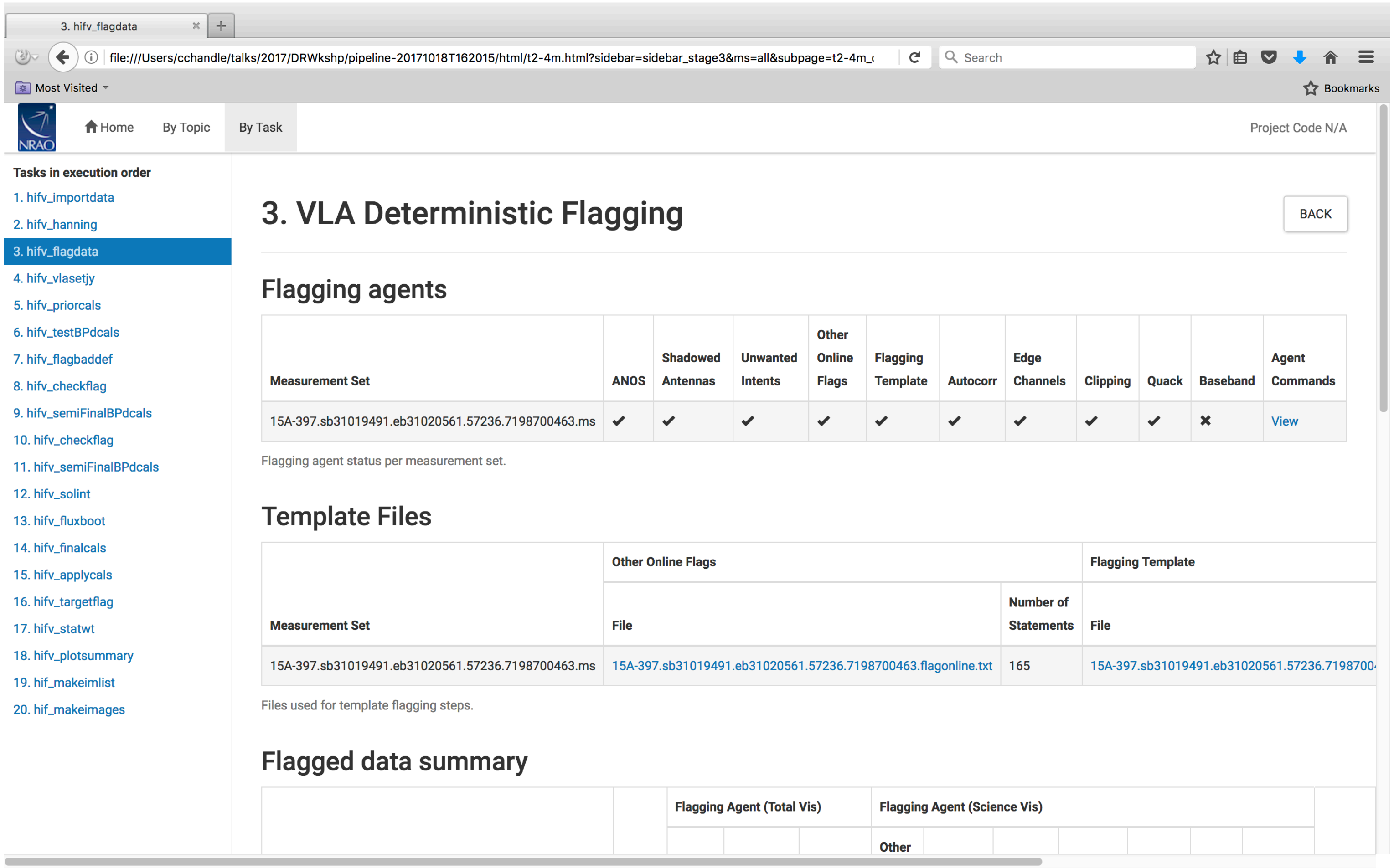
Task		QA Score	
1. **hifv_importdata**: Register VLA measurement sets with the pipeline	No QA		N/A
2. **hifv_hanning**: VLA Hanning Smoothing	No QA		N/A
3. **hifv_flagdata**: VLA Deterministic flagging			0.98
4. **hifv_vlasetjy**: Set calibrator model visibilities	No QA		N/A
5. **hifv_priorcals**: Priorcals (gaincurves, opacities, antenna positions corrections, rq gains, and switched power)	No QA		N/A
6. **hifv_testBPdcals**: Initial test calibrations	No QA		N/A
7. **hifv_flagbaddef**: Flag bad deformatters	No QA		N/A
8. **hifv_checkflag**: Flag possible RFI using rflag and tfcrop	No QA		N/A
9. **hifv_semiFinalBPdcals**: Semi-final delay and bandpass calibrations	No QA		N/A
10. **hifv_checkflag**: Flag possible RFI using rflag and tfcrop	No QA		N/A
11. **hifv_semiFinalBPdcals**: Semi-final delay and bandpass calibrations	No QA		N/A
12. **hifv_solint**: Determine solint and Test gain calibrations	No QA		N/A
13. **hifv_fluxboot**: Gain table for flux density bootstrapping	No QA		N/A
14. **hifv_finalcals**: Final Calibration Tables	No QA		N/A

file:///Users/cchandle/talks/2017/DRWkshp/pipeline-20171018T162015/html/t1-4.html

Pipeline Weblog

- The following pipeline steps provide key checks for calibration quality:
  - hifv_flagdata *deterministic flagged data fraction*
  - hifv_priorcals *gain compression due to RFI (or the Sun)*
  - hifv_solint *solution intervals used for short/long phase cals*
  - hifv_fluxboot *fitted calibrator flux densities and spectral indices*
  - hifv_finalcals *final calibration tables to be applied to the data*
  - hifv_plotsummary *some useful diagnostic plots of calibrated data*
- If something funny shows up in these steps you can look at the intermediate steps to see what might have gone wrong

Deterministic Flags (hifv_flagdata)



3. hifv_flagdata

file:///Users/cchandle/talks/2017/DRWkshp/pipeline-20171018T162015/html/t2-4m.html?sidebar=sidebar_stage3&ms=all&subpage=t2-4m_

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Tasks in execution order

1. hifv_importdata
2. hifv_hanning
3. hifv_flagdata
4. hifv_vlasetjy
5. hifv_priorcals
6. hifv_testBPdcals
7. hifv_flagbaddef
8. hifv_checkflag
9. hifv_semiFinalBPdcals
10. hifv_checkflag
11. hifv_semiFinalBPdcals
12. hifv_solint
13. hifv_fluxboot
14. hifv_finalcals
15. hifv_applycals
16. hifv_targetflag
17. hifv_statwt
18. hifv_plotsummary
19. hif_makeimlist
20. hif_makeimages

3. VLA Deterministic Flagging

BACK

Flagging agents

Measurement Set	ANOS	Shadowed Antennas	Unwanted Intents	Other Online Flags	Flagging Template	Autocorr	Edge Channels	Clipping	Quack	Baseband	Agent Commands
15A-397.sb31019491.eb31020561.57236.7198700463.ms	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖	View

Flagging agent status per measurement set.

Template Files

Measurement Set	Other Online Flags		Flagging Template
	File	Number of Statements	File
15A-397.sb31019491.eb31020561.57236.7198700463.ms	15A-397.sb31019491.eb31020561.57236.7198700463.flagonline.txt	165	15A-397.sb31019491.eb31020561.57236.719870[0…]

Files used for template flagging steps.

Flagged data summary

		Flagging Agent (Total Vis)	Flagging Agent (Science Vis)
			Other

Deterministic Flags (hifv_flagdata)

3. hifv_flagdata

file:///Users/cchandle/talks/2017/DRWkshp/pipeline-20171018T162015/html/t2-4m.html?sidebar=sidebar_stage3&ms=all&subpage=t2-4m_(

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Tasks in execution order

1. hifv_importdata
2. hifv_hanning
3. hifv_flagdata
4. hifv_vlasetjy
5. hifv_priorcals
6. hifv_testBPdcals
7. hifv_flagbaddef
8. hifv_checkflag
9. hifv_semiFinalBPdcals
10. hifv_checkflag
11. hifv_semiFinalBPdcals
12. hifv_solint
13. hifv_fluxboot
14. hifv_finalcals
15. hifv_applycals
16. hifv_targetflag
17. hifv_statwt
18. hifv_plotsummary
19. hif_makeimlist
20. hif_makeimages

Data Selection (by intent)	Before Task	ANOS	Shadowed Antennas	Unwanted Intents	Other Online Flags	Flagging Template	Autocorr	Edge Channels	Clipping	Quack	Baseband	Total Science
All Data	3.12%	19.83%	0.00%	18.02%	4.86%	0.00%	0.00%	6.14%	0.00%	0.00%	0.00%	11.00%
Science Spectral Windows	3.12%	19.83%	0.00%	18.02%	4.86%	0.00%	0.00%	6.14%	0.00%	0.00%	0.00%	11.00%
Bandpass	3.12%	1.09%	0.00%	0.00%	0.17%	0.00%	0.00%	6.44%	0.00%	0.00%	0.00%	6.62%
Flux	3.12%	1.09%	0.00%	0.00%	0.17%	0.00%	0.00%	6.44%	0.00%	0.00%	0.00%	6.62%
Phase	3.12%	41.29%	0.00%	0.00%	0.00%	0.00%	0.00%	6.45%	0.00%	0.00%	0.00%	6.45%
Target	3.12%	6.12%	0.00%	0.00%	5.65%	0.00%	0.00%	6.09%	0.00%	0.00%	0.00%	11.73%
15A-397.sb31019491.eb31020561.57236.7198700463.ms	3.12%	19.83%	0.00%	18.02%	4.86%	0.00%	0.00%	6.14%	0.00%	0.00%	0.00%	11.00%

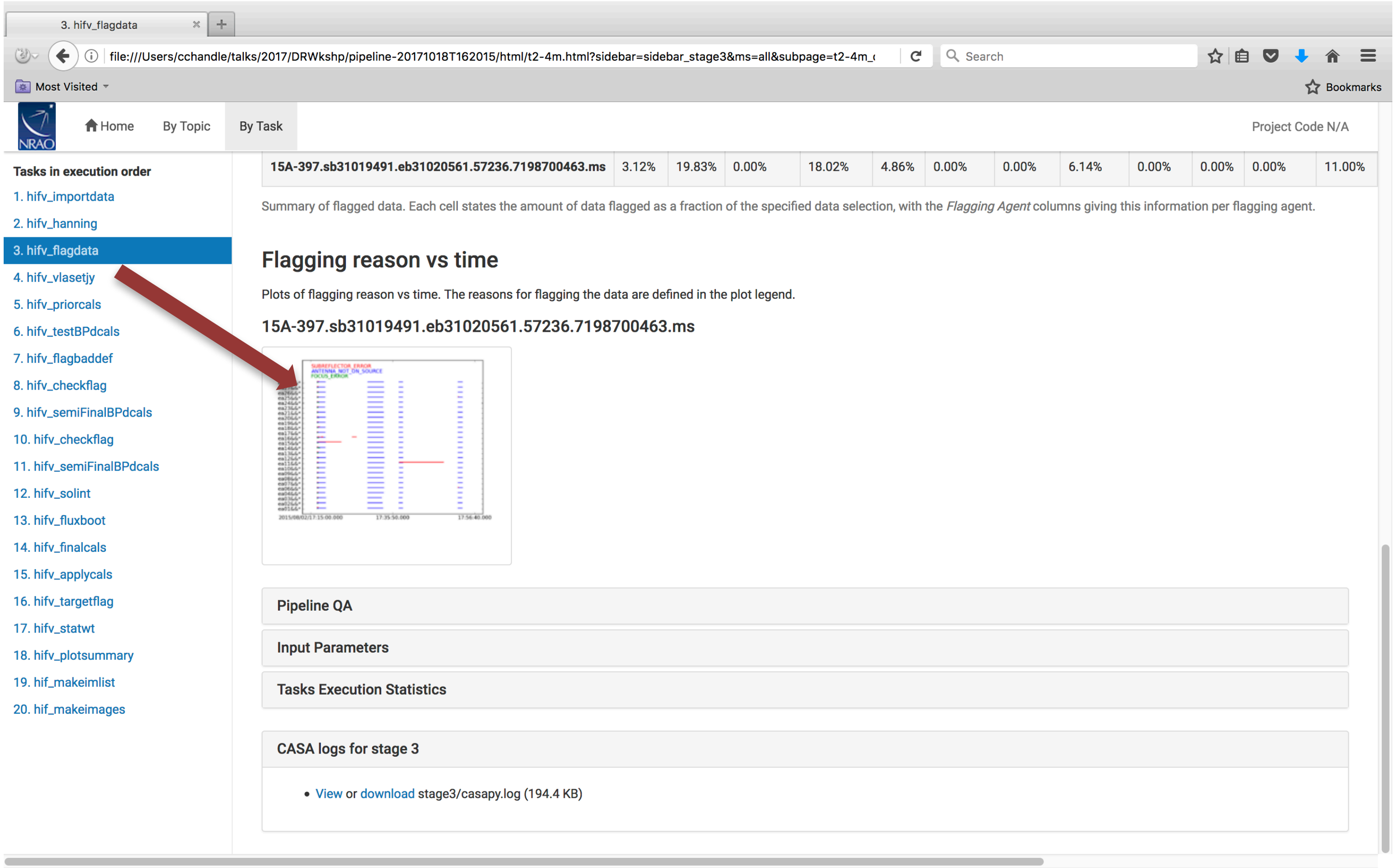
Summary of flagged data. Each cell states the amount of data flagged as a fraction of the specified data selection, with the *Flagging Agent* columns giving this information per flagging agent.

Flagging reason vs time

Plots of flagging reason vs time. The reasons for flagging the data are defined in the plot legend.

15A-397.sb31019491.eb31020561.57236.7198700463.ms

Deterministic Flags (hifv_flagdata)



3. hifv_flagdata

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Tasks in execution order

1. hifv_importdata
2. hifv_hanning
3. hifv_flagdata
4. hifv_vlasetjy
5. hifv_priorcals
6. hifv_testBPdcals
7. hifv_flagbaddef
8. hifv_checkflag
9. hifv_semiFinalBPdcals
10. hifv_checkflag
11. hifv_semiFinalBPdcals
12. hifv_solint
13. hifv_fluxboot
14. hifv_finalcals
15. hifv_applycals
16. hifv_targetflag
17. hifv_statwt
18. hifv_plotsummary
19. hif_makeimlist
20. hif_makeimages

15A-397.sb31019491.eb31020561.57236.7198700463.ms	3.12%	19.83%	0.00%	18.02%	4.86%	0.00%	0.00%	6.14%	0.00%	0.00%	0.00%	11.00%

Summary of flagged data. Each cell states the amount of data flagged as a fraction of the specified data selection, with the *Flagging Agent* columns giving this information per flagging agent.

Flagging reason vs time

Plots of flagging reason vs time. The reasons for flagging the data are defined in the plot legend.

15A-397.sb31019491.eb31020561.57236.7198700463.ms

Pipeline QA

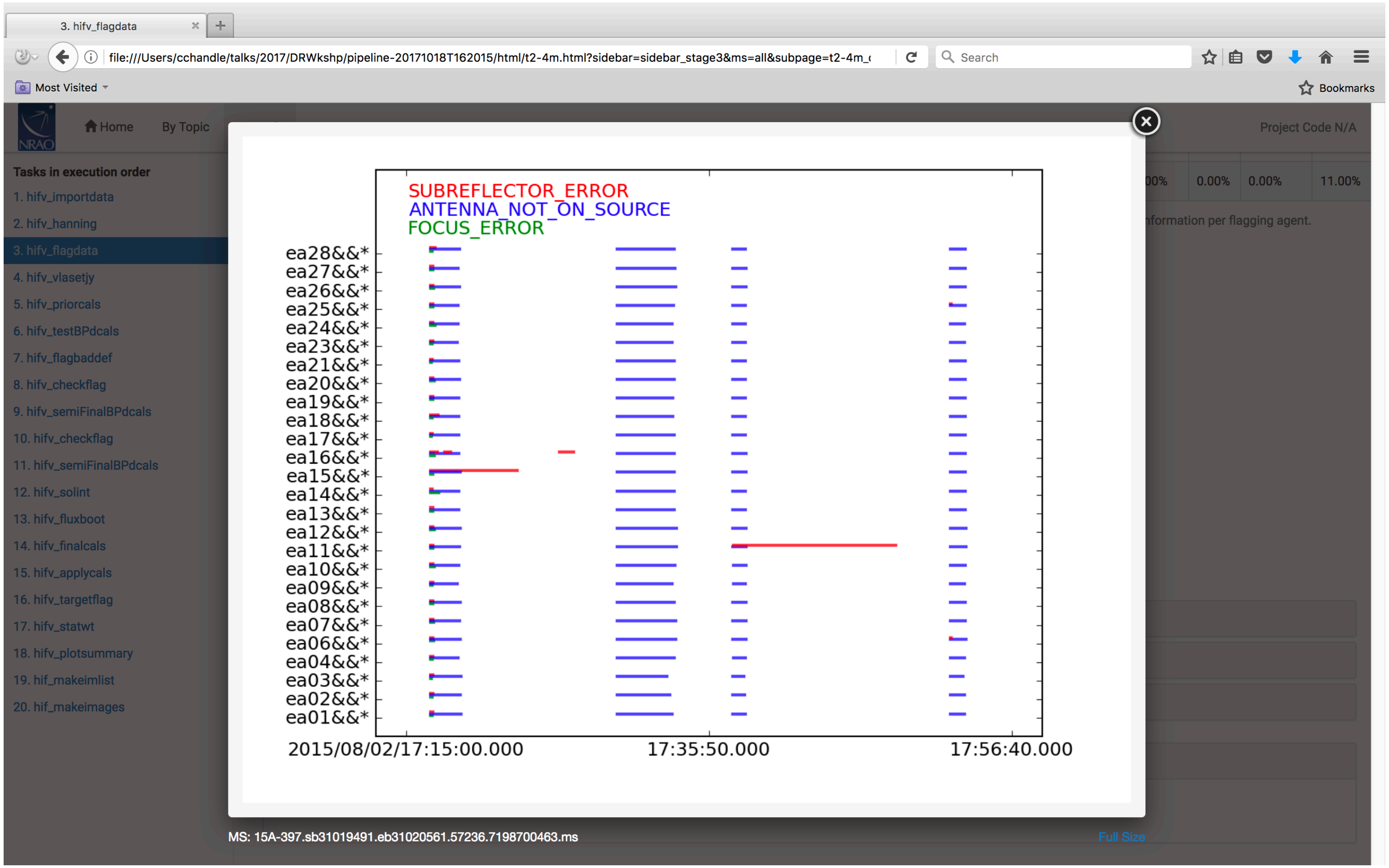
Input Parameters

Tasks Execution Statistics

CASA logs for stage 3

- View or download stage3/casapy.log (194.4 KB)

Deterministic Flags (hifv_flagdata)



Prior Calibrations (hifv_priorcals)

5. hifv_priorcals

file:///Users/cchandle/talks/2017/DRWkshp/pipeline-20171018T162015/html/t2-4m.html?sidebar=sidebar_stage5&ms=all&subpage=t2-4m_(

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17. hifv_statwt
18. hifv_plotsummary
19. hif_makeimlist
20. hif_makeimages

5. Prior calibrations

BACK

Gain curves, opacities, antenna position corrections, requantizer gains, TEC maps, and switched power plots using the CASA task **gencal**.

Gain Curves

Gain curve table written to:

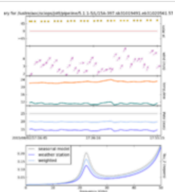
15A-397.sb31019491.eb31020561.57236.7198700463.ms.hifv_priorcals.s5_3.gc.tbl

Opacities

Opacities written to:

15A-397.sb31019491.eb31020561.57236.7198700463.ms.hifv_priorcals.s5_4.opac.tbl

15A-397.sb31019491.eb31020561.57236.7198700463.ms

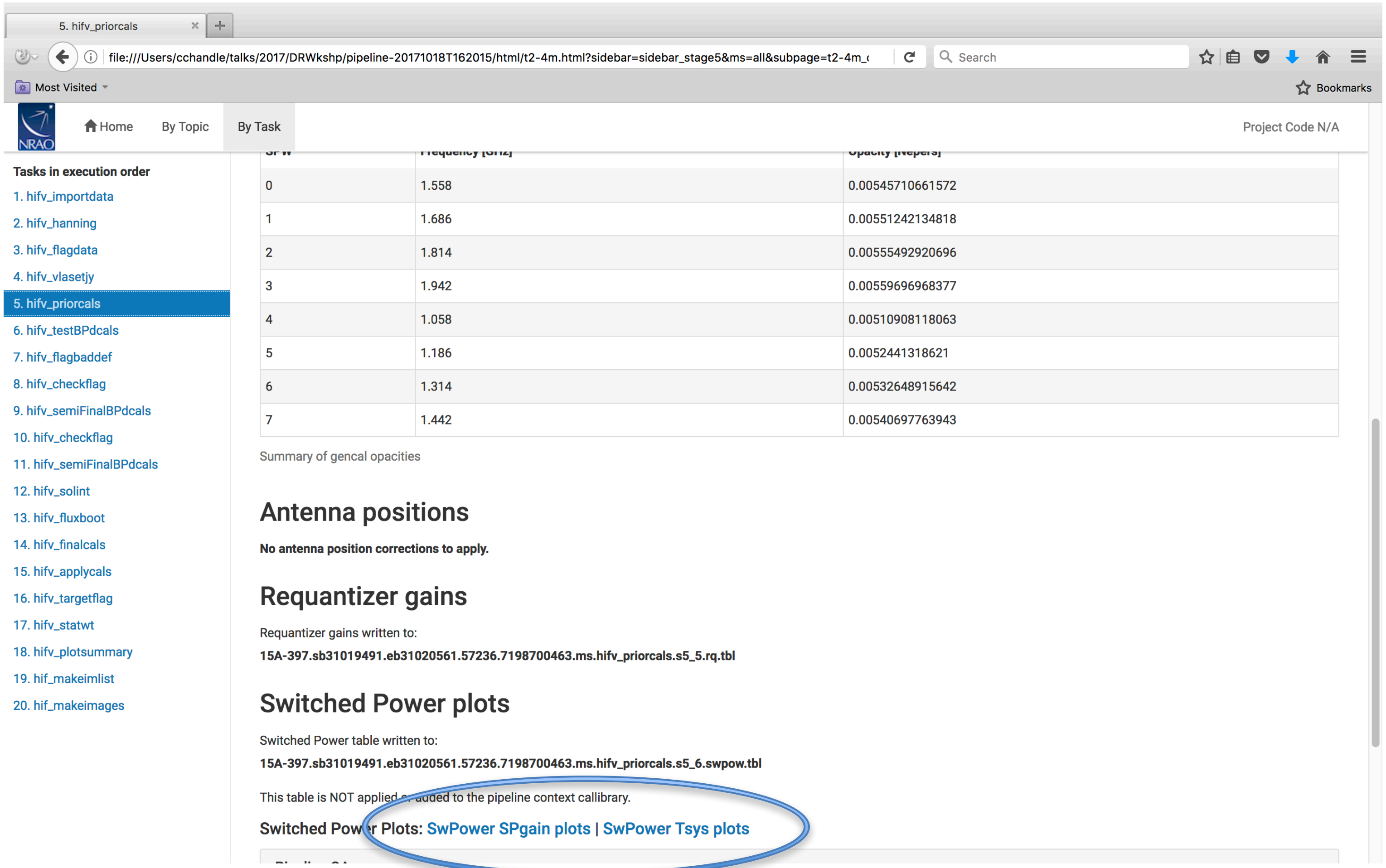


Opacities

SPW	Frequency [GHz]	Opacity [Nepers]

file:///Users/cchandle/talks/2017/DRWkshp/pipeline-20171018T162015/html/stage6/t2-4m_details-container.html

Prior Calibrations (hifv_priorcals)



5. hifv_priorcals

file:///Users/cchandle/talks/2017/DRWkshp/pipeline-20171018T162015/html/t2-4m.html?sidebar=sidebar_stage5&ms=all&subpage=t2-4m_(

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15. hifv_applycals
16. hifv_targetflag
17. hifv_statwt
18. hifv_plotsummary
19. hif_makeimlist
20. hif_makeimages

SPW	Frequency [GHz]	Opacity [Nepers]
0	1.558	0.00545710661572
1	1.686	0.00551242134818
2	1.814	0.00555492920696
3	1.942	0.00559696968377
4	1.058	0.00510908118063
5	1.186	0.0052441318621
6	1.314	0.00532648915642
7	1.442	0.00540697763943

Summary of gencal opacities

Antenna positions

No antenna position corrections to apply.

Requantizer gains

Requantizer gains written to:

15A-397.sb31019491.eb31020561.57236.7198700463.ms.hifv_priorcals.s5_5.rq.tbl

Switched Power plots

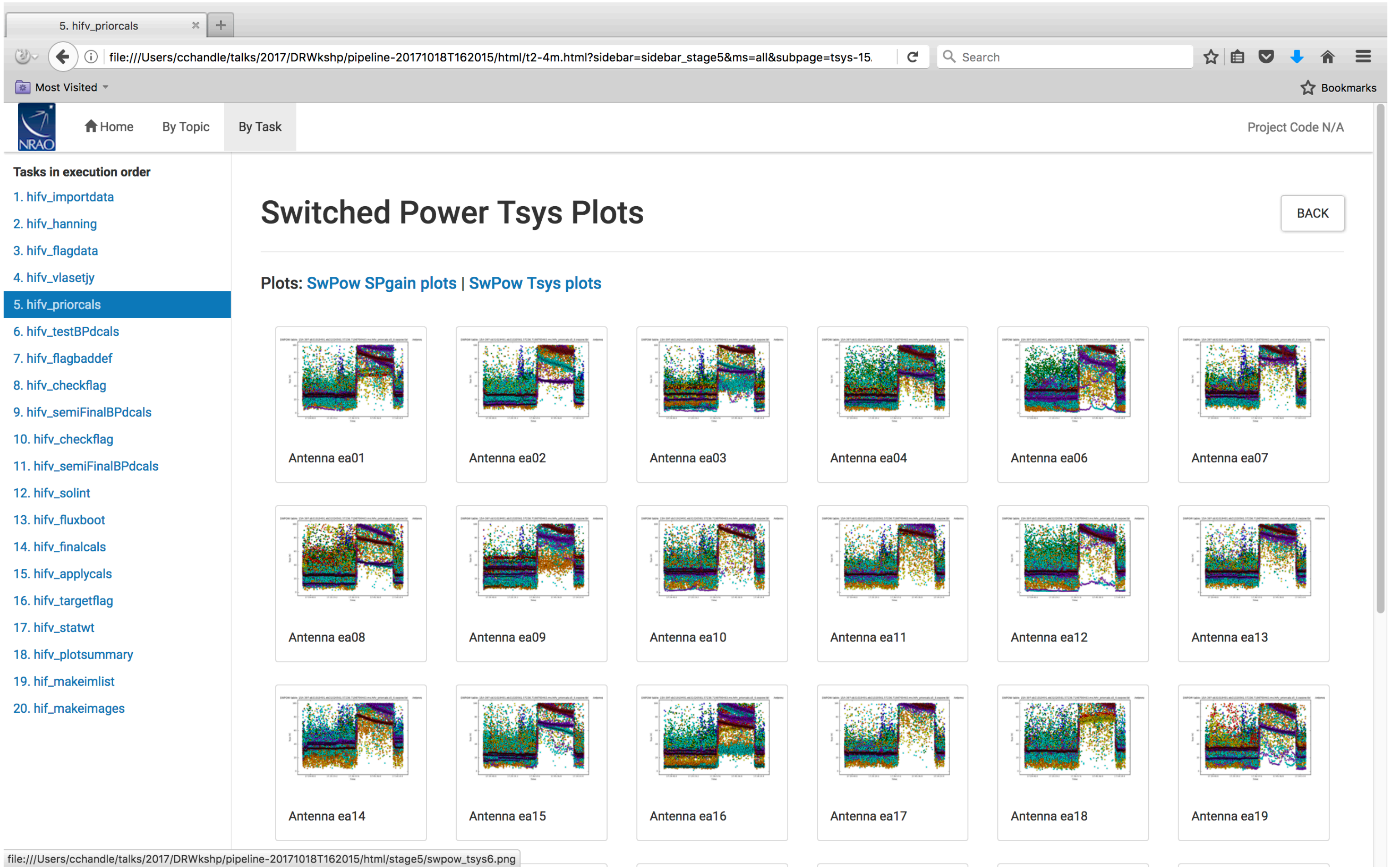
Switched Power table written to:

15A-397.sb31019491.eb31020561.57236.7198700463.ms.hifv_priorcals.s5_6.swpow.tbl

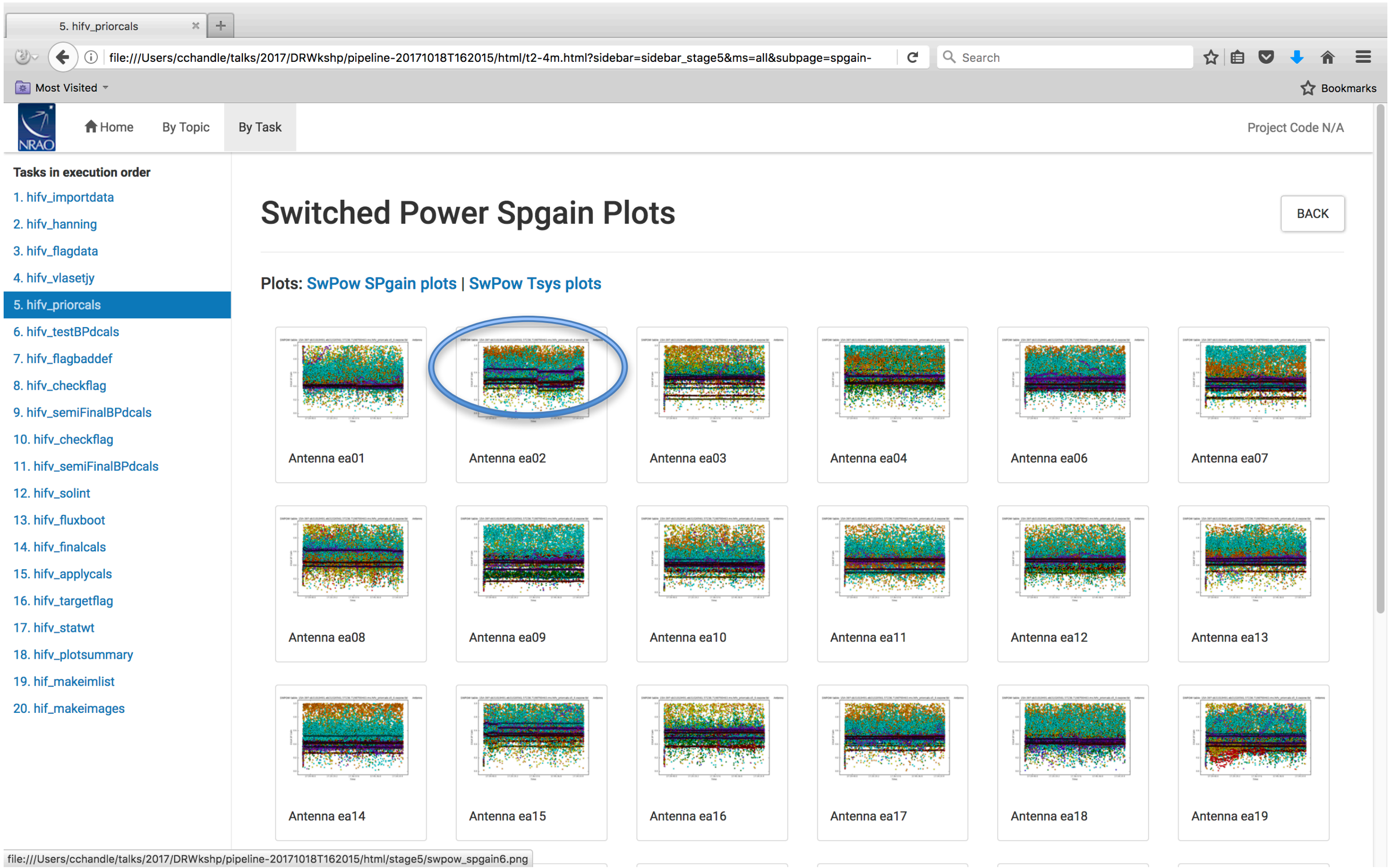
This table is NOT applied or added to the pipeline context callibrary.

Switched Power Plots: SwPower SPgain plots | SwPower Tsys plots

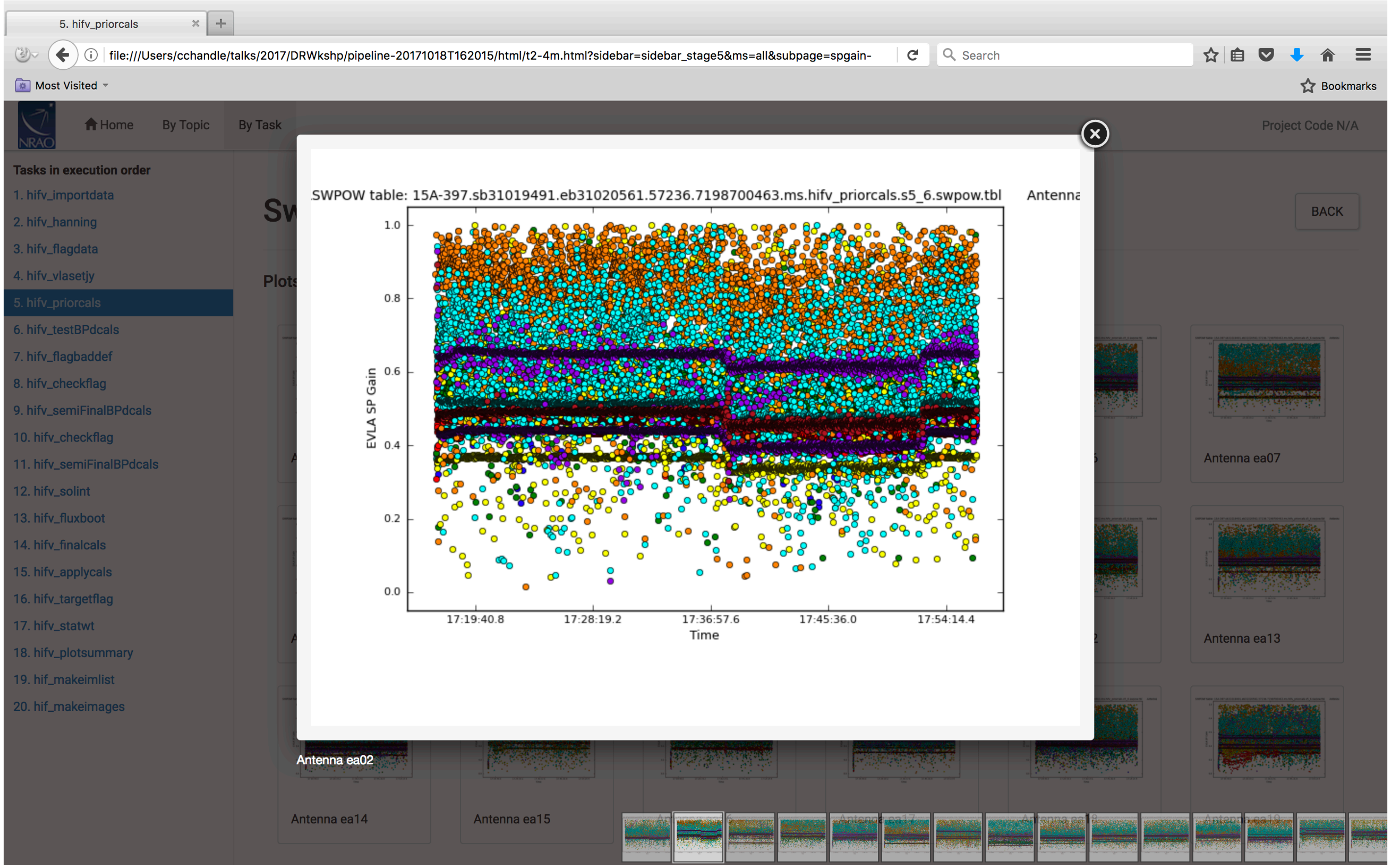
Prior Calibrations (hifv_priorcals)



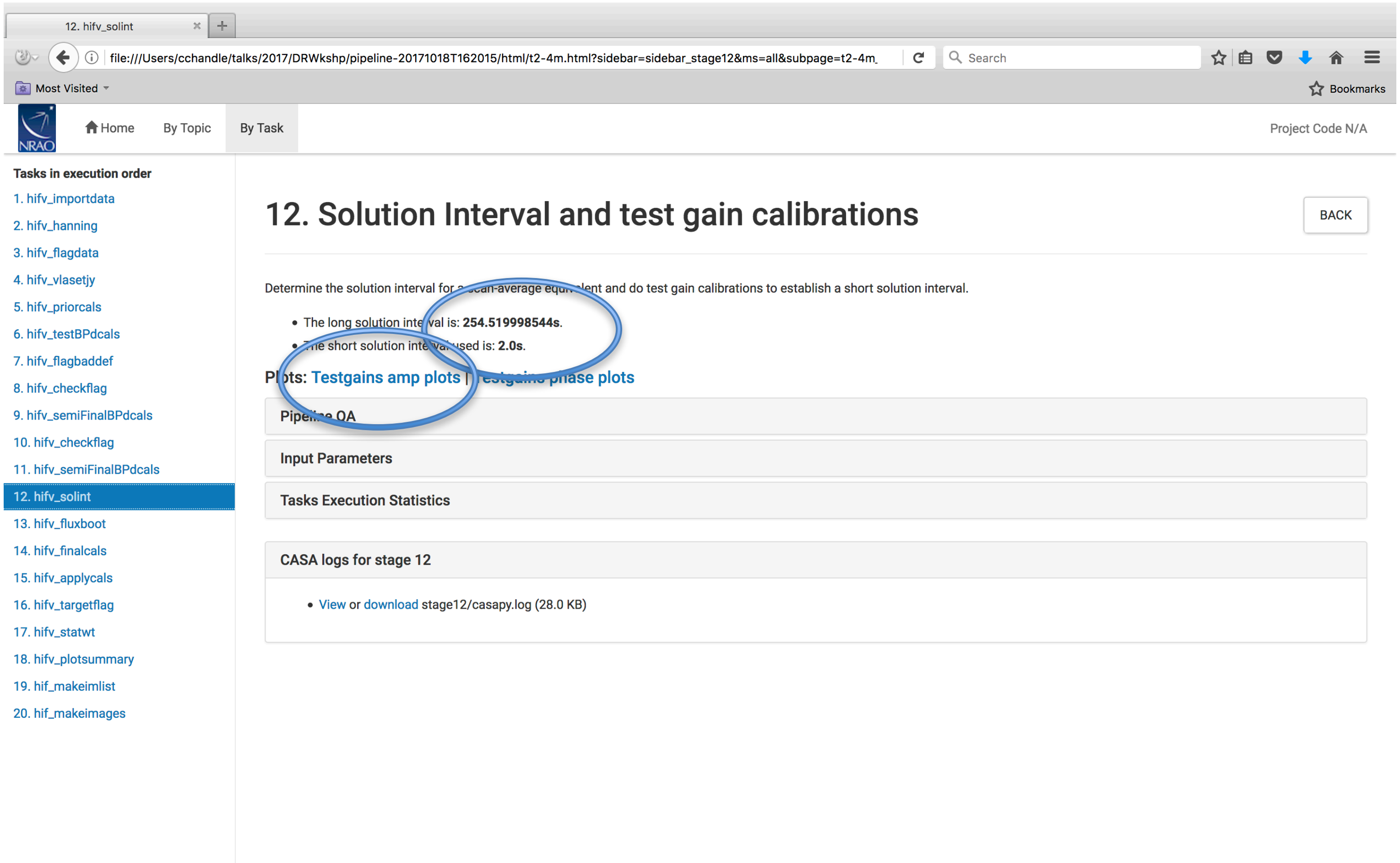
Prior Calibrations (hifv_priorcals)



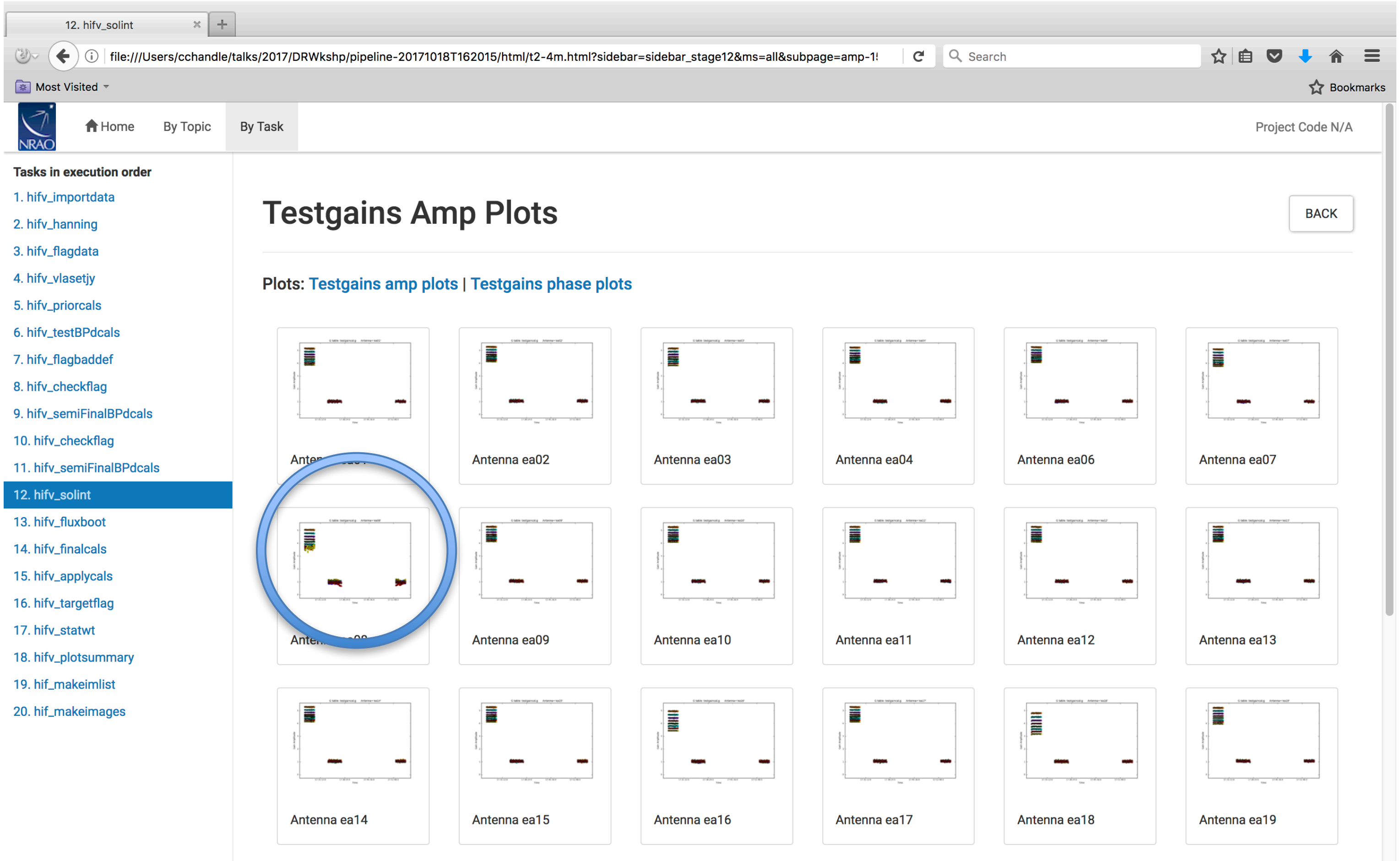
Prior Calibrations (hifv_priorcals)



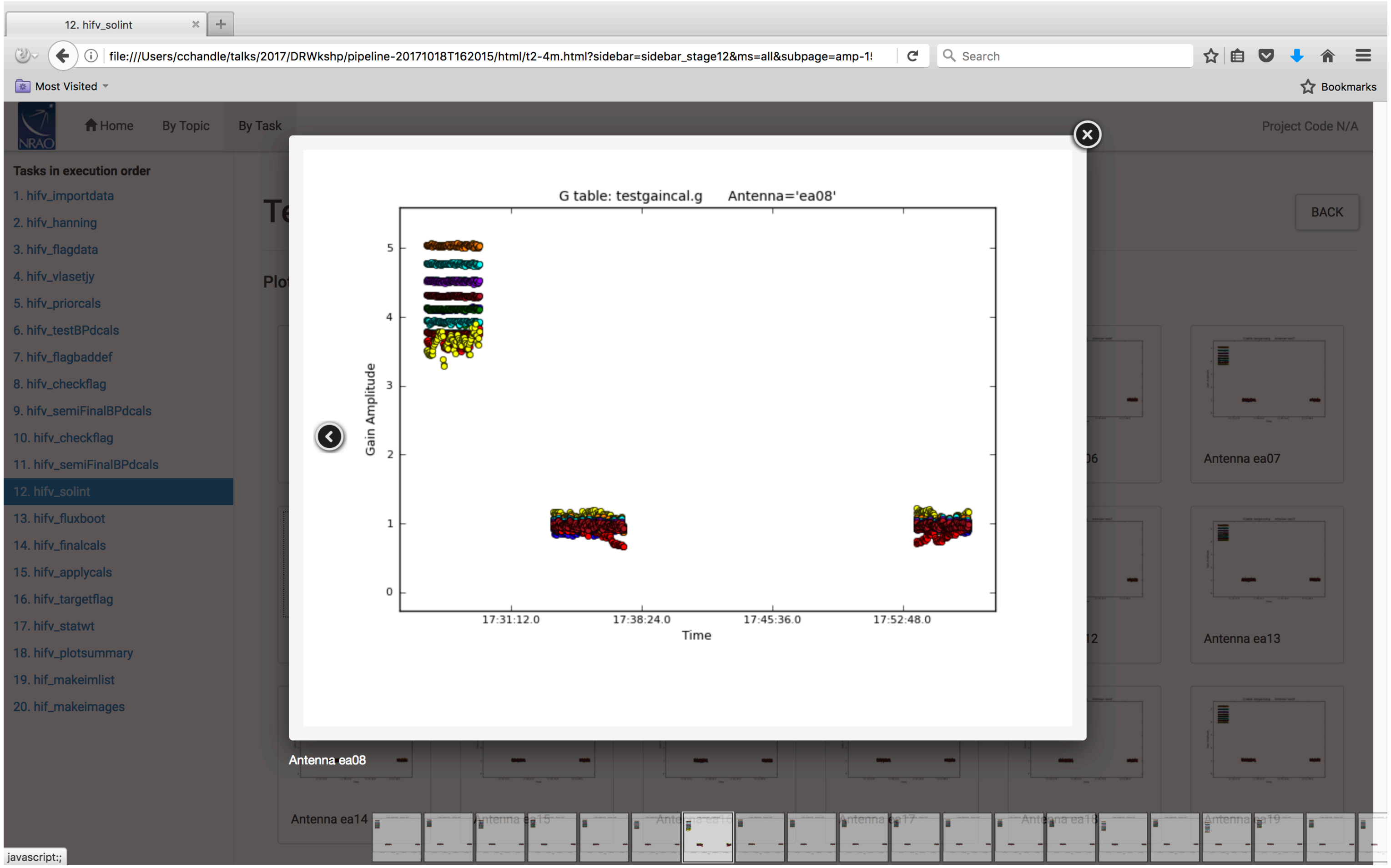
Gain Solution Intervals (hifv_solint)



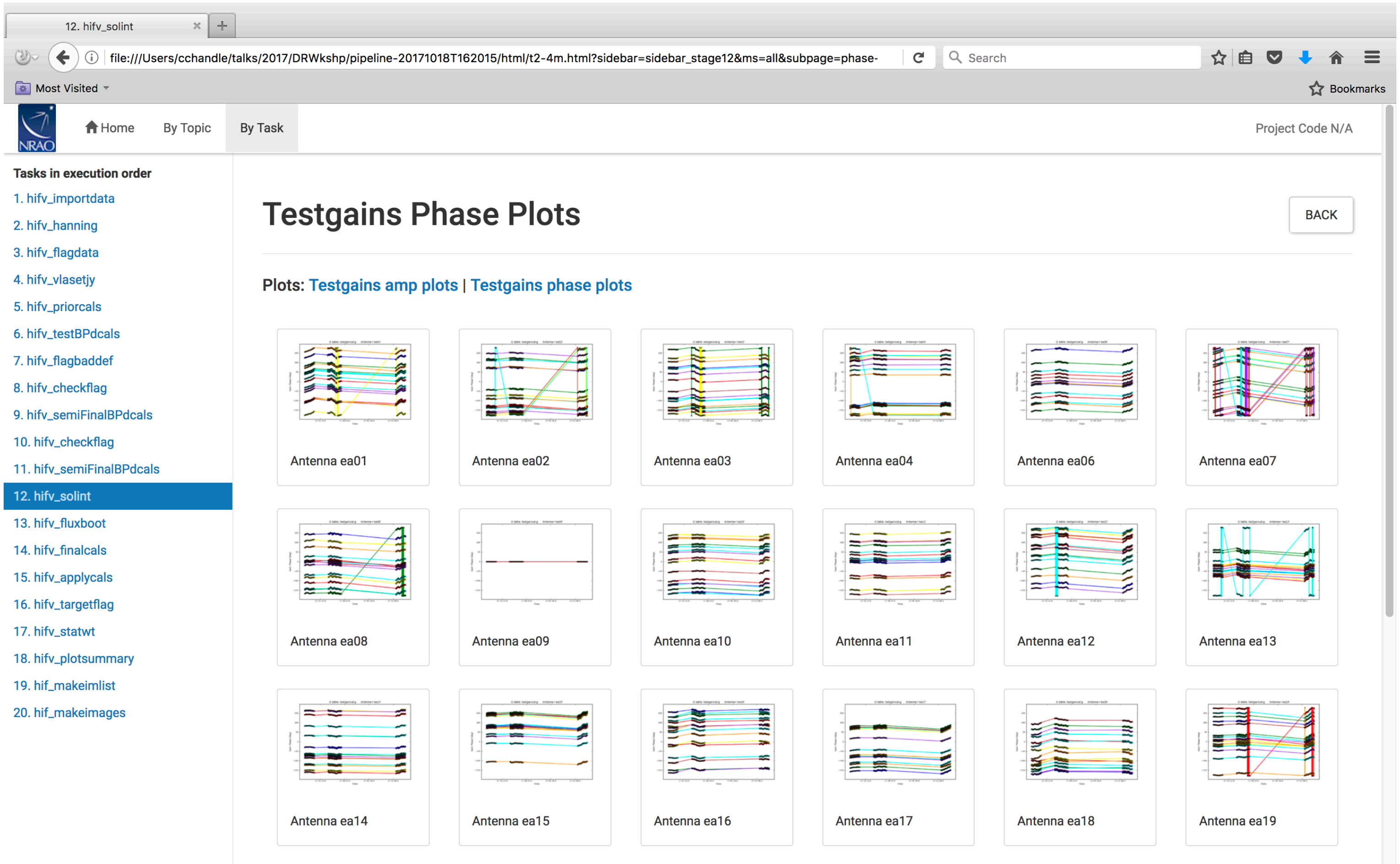
Gain Solution Intervals (hifv_solint)



Gain Solution Intervals (hifv_solint)



Gain Solution Intervals (hifv_solint)



Flux Density Bootstrapping (hifv_fluxboot)

13. hifv_fluxboot

file:///Users/cchandle/talks/2017/DRWkshp/pipeline-20171018T162015/html/t2-4m.html?sidebar=sidebar_stage13&ms=all&subpage=t2-4m_

Most Visited

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Home | By Topic | By Task

Project Code N/A

Tasks in execution order

1. hifv_importdata
2. hifv_hanning
3. hifv_flagdata
4. hifv_vlasetjy
5. hifv_priorcals
6. hifv_testBPdcals
7. hifv_flagbaddef
8. hifv_checkflag
9. hifv_semiFinalBPdcals
10. hifv_checkflag
11. hifv_semiFinalBPdcals
12. hifv_solint
13. hifv_fluxboot
14. hifv_finalcals
15. hifv_applycals
16. hifv_targetflag
17. hifv_statwt
18. hifv_plotsummary
19. hif_makeimlist
20. hif_makeimages

13. Flux density bootstrapping and spectral index fitting

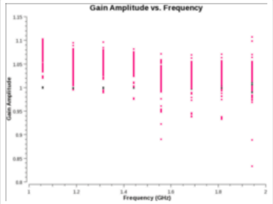
BACK

Make a gain table that includes gain and opacity corrections for final amp cal and for flux density bootstrapping.

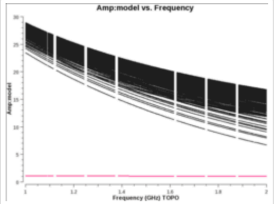
Fit the spectral index of calibrators with a power-law and put the fit in the model column.

Fluxboot summary plots

15A-397.sb31019491.eb31020561.57236.7198700463.ms



Caltable: fluxgaincal.g



Model calibrator

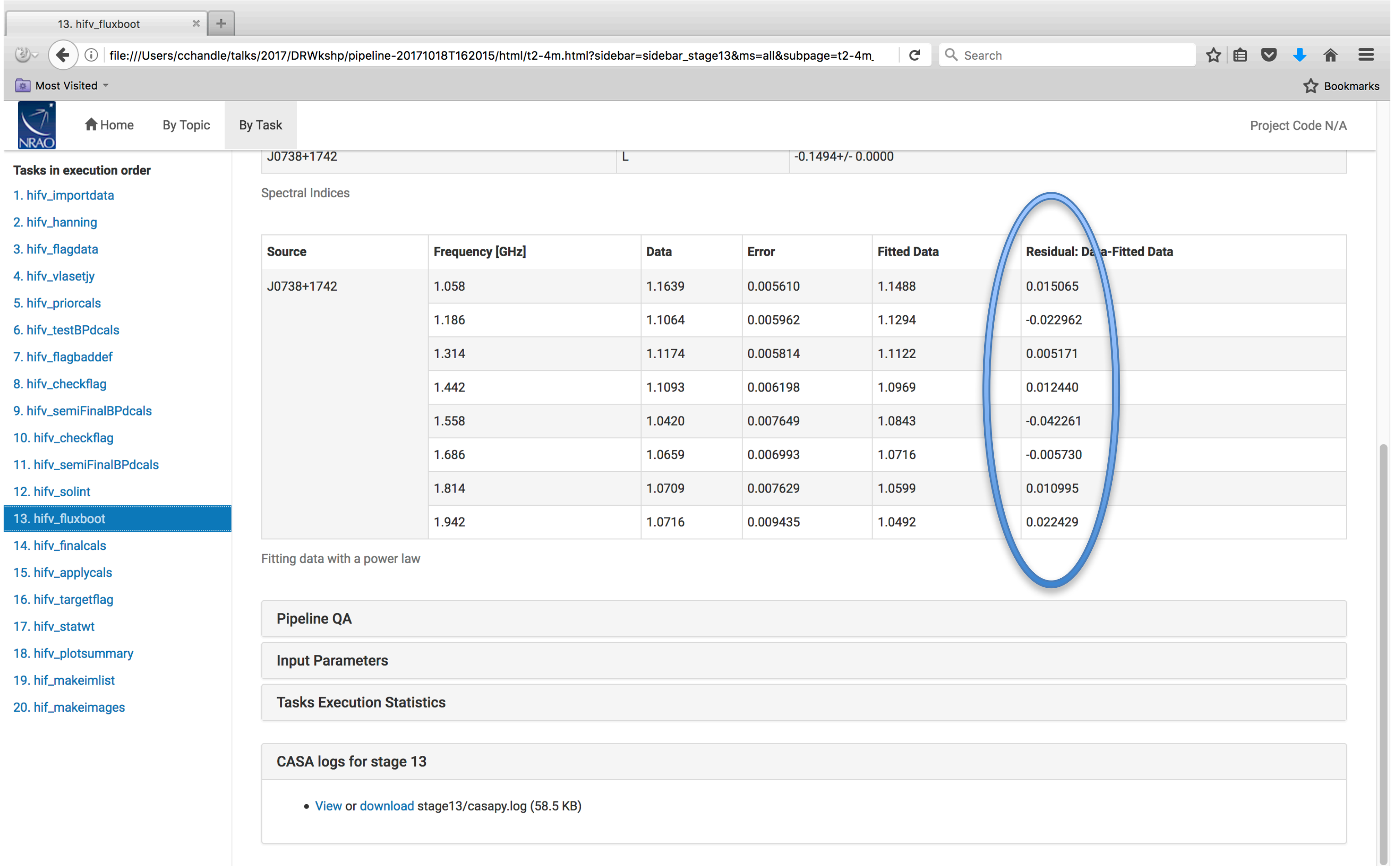
Source	Band	Fitted Spectral Index
J0738+1742	L	-0.1494+/- 0.000

Spectral Indices

Source	Frequency [GHz]	Data	Error	Fitted Data	Residual: Data-Fitted Data

file:///Users/cchandle/talks/2017/DRWkshp/pipeline-20171018T162015/html/stage13/fluxgaincalFluxDensities-15A-397.sb31019491.eb31020561.57236.7198700463.ms-summary.png

Flux Density Bootstrapping (hifv_fluxboot)



13. hifv_fluxboot

file:///Users/cchandle/talks/2017/DRWkshp/pipeline-20171018T162015/html/t2-4m.html?sidebar=sidebar_stage13&ms=all&subpage=t2-4m

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Home | By Topic | By Task | Project Code N/A

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3. hifv_flagdata
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8. hifv_checkflag
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10. hifv_checkflag
11. hifv_semiFinalBPdcals
12. hifv_solint
13. hifv_fluxboot
14. hifv_finalcals
15. hifv_applycals
16. hifv_targetflag
17. hifv_statwt
18. hifv_plotsummary
19. hif_makeimlist
20. hif_makeimages

J0738+1742	L	-0.1494+/- 0.0000

Spectral Indices

Source	Frequency [GHz]	Data	Error	Fitted Data	Residual: Data-Fitted Data
J0738+1742	1.058	1.1639	0.005610	1.1488	0.015065
	1.186	1.1064	0.005962	1.1294	-0.022962
	1.314	1.1174	0.005814	1.1122	0.005171
	1.442	1.1093	0.006198	1.0969	0.012440
	1.558	1.0420	0.007649	1.0843	-0.042261
	1.686	1.0659	0.006993	1.0716	-0.005730
	1.814	1.0709	0.007629	1.0599	0.010995
	1.942	1.0716	0.009435	1.0492	0.022429

Fitting data with a power law

Pipeline QA

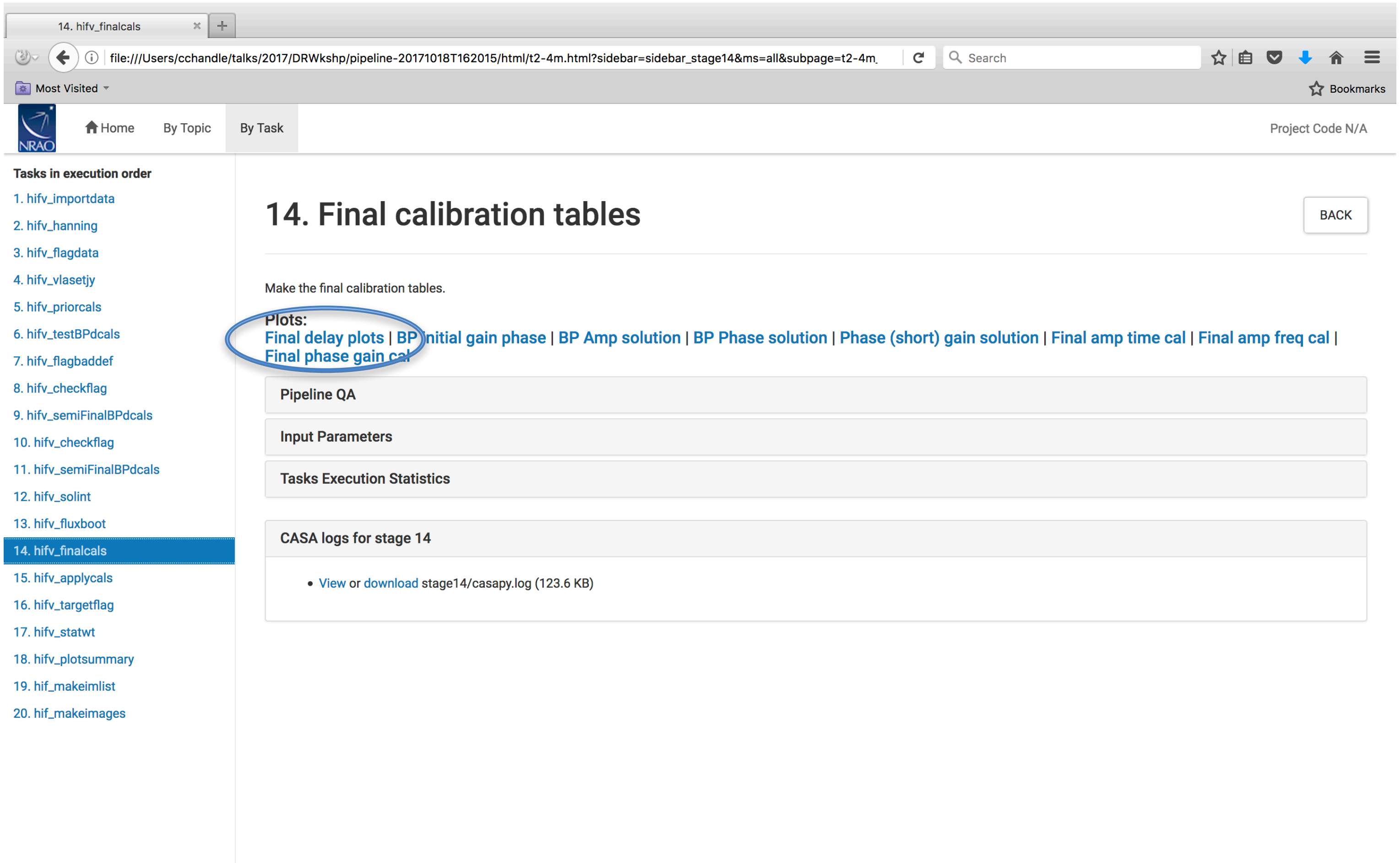
Input Parameters

Tasks Execution Statistics

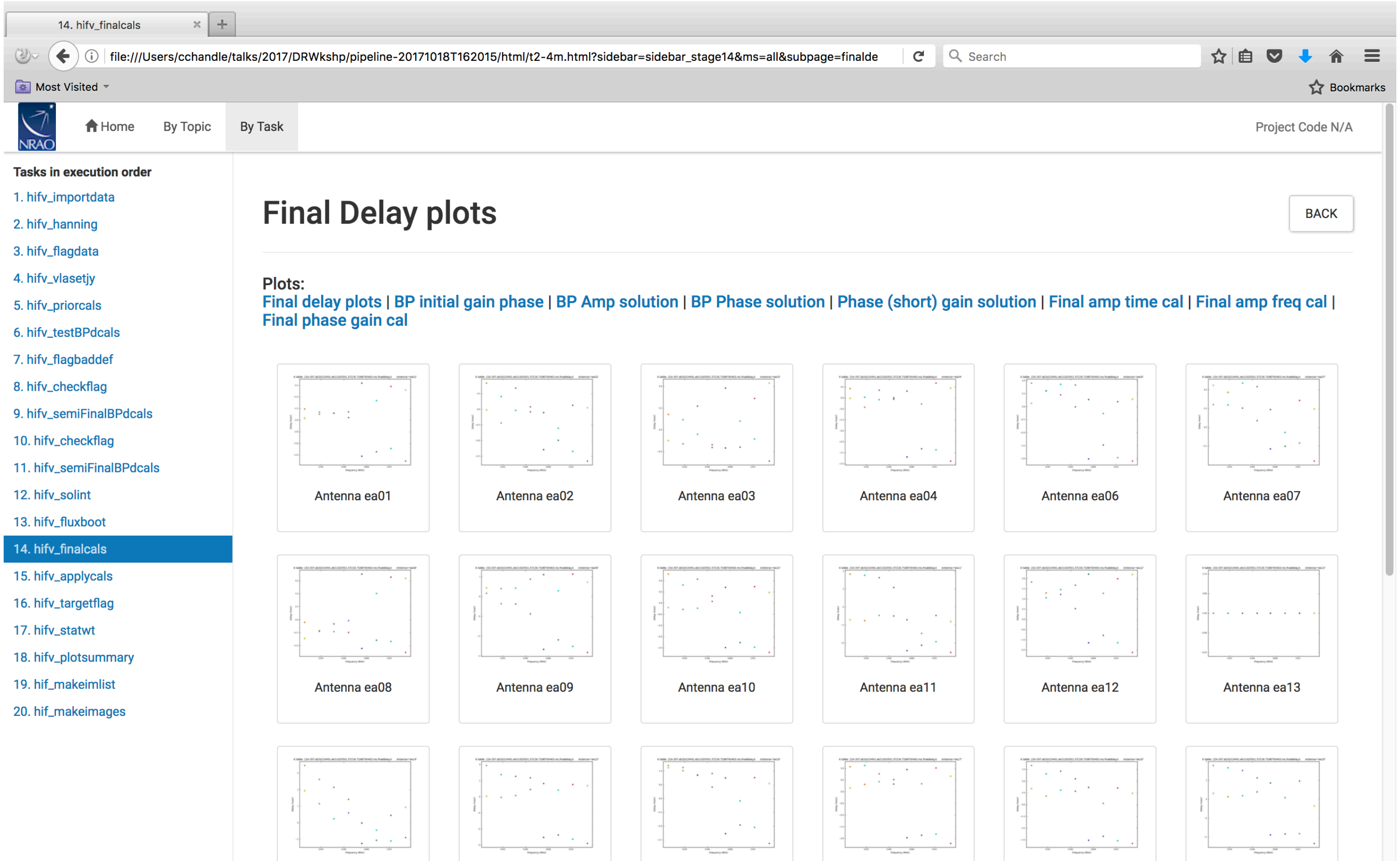
CASA logs for stage 13

- View or download stage13/casapy.log (58.5 KB)

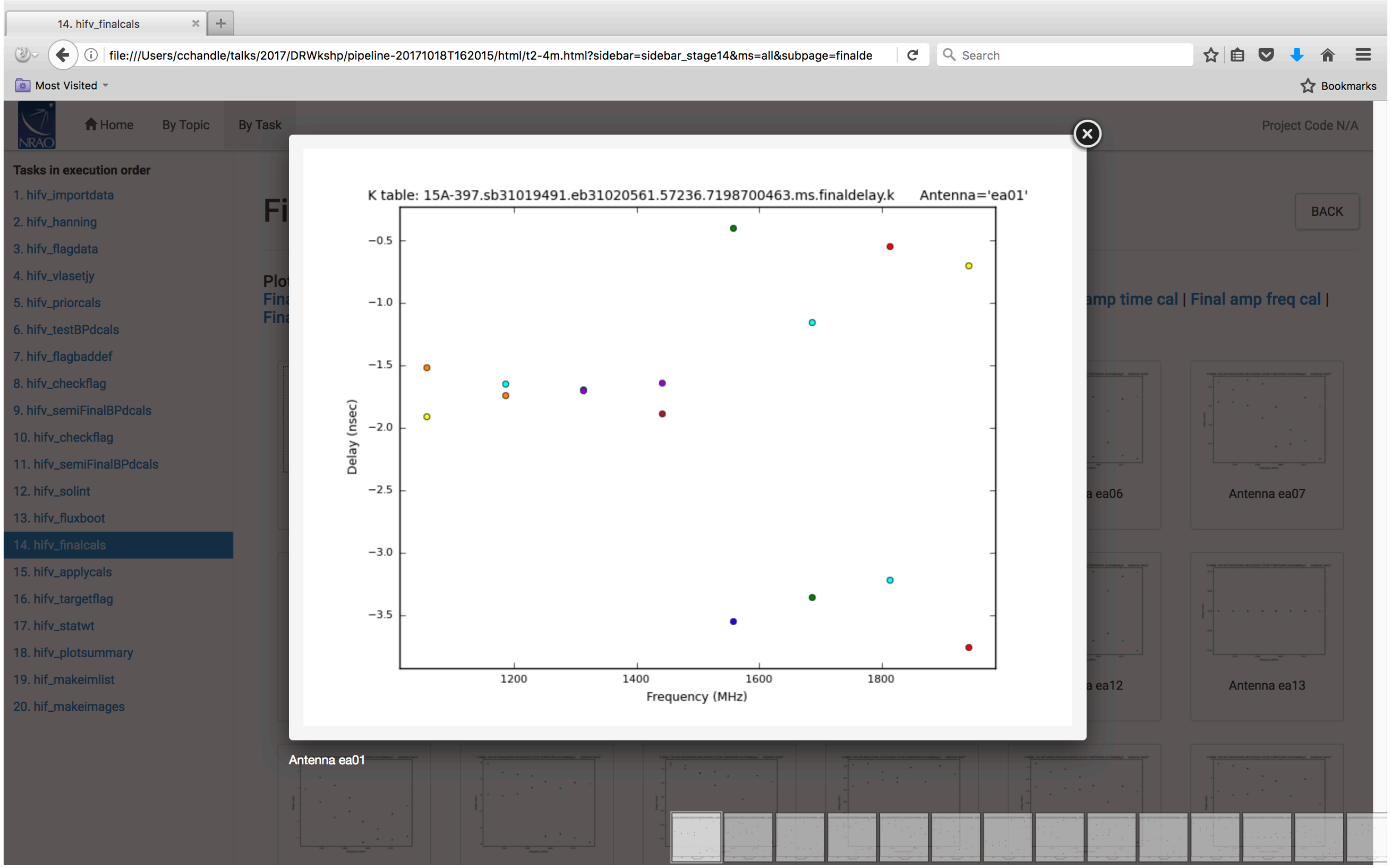
Final Calibration Tables (hifv_finalcals)



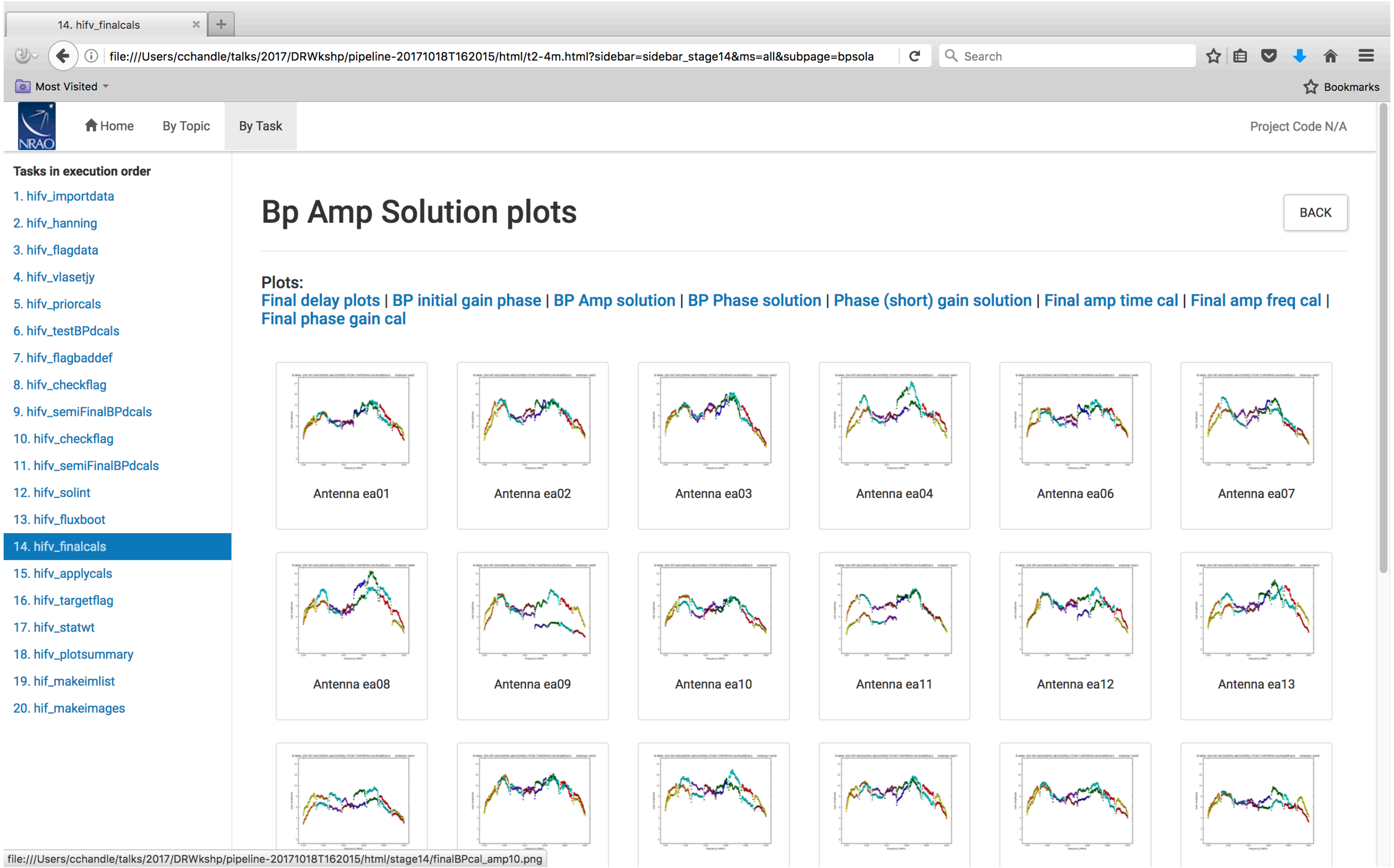
Final Calibration Tables (hifv_finalcals)



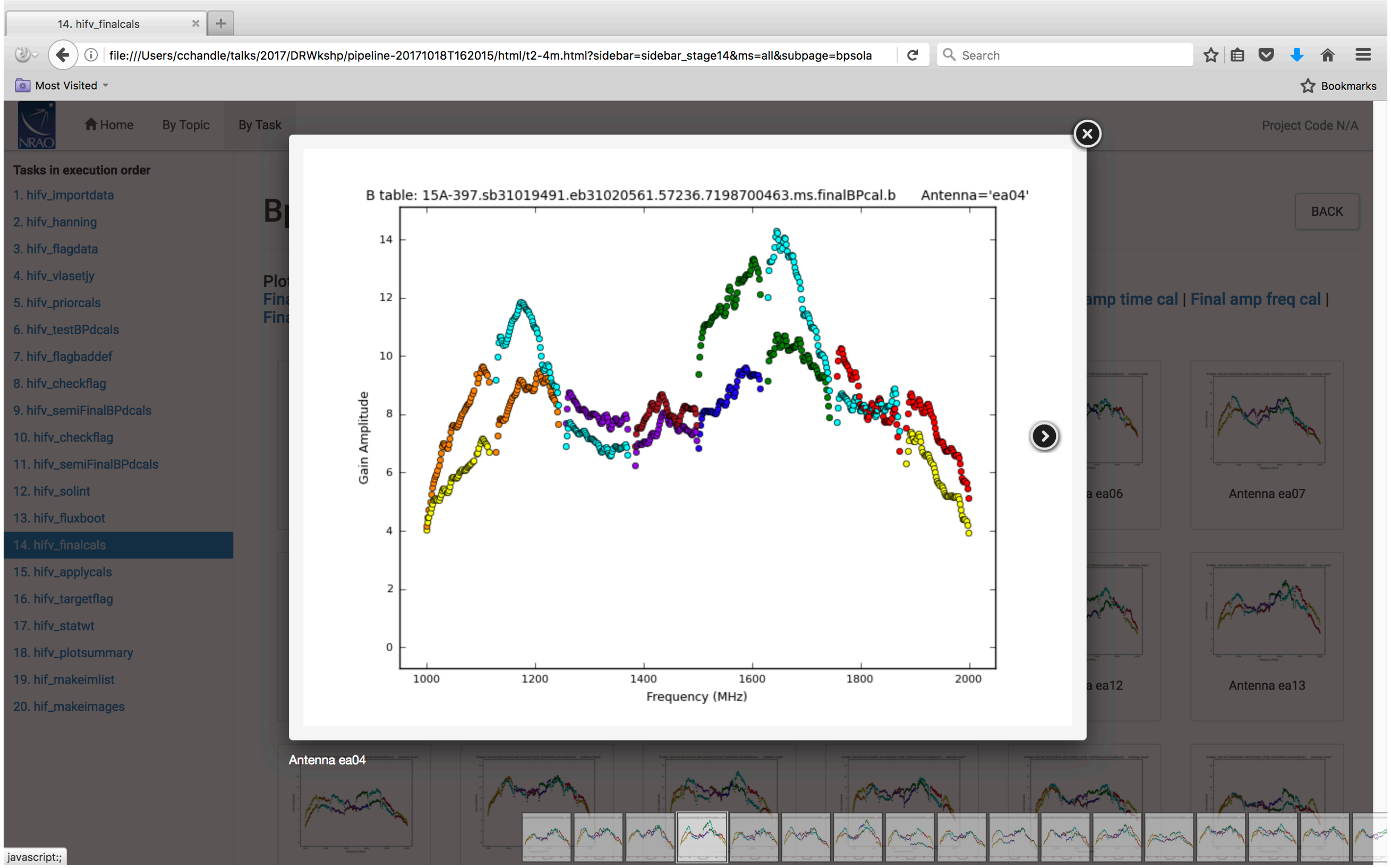
Final Calibration Tables (hifv_finalcals)



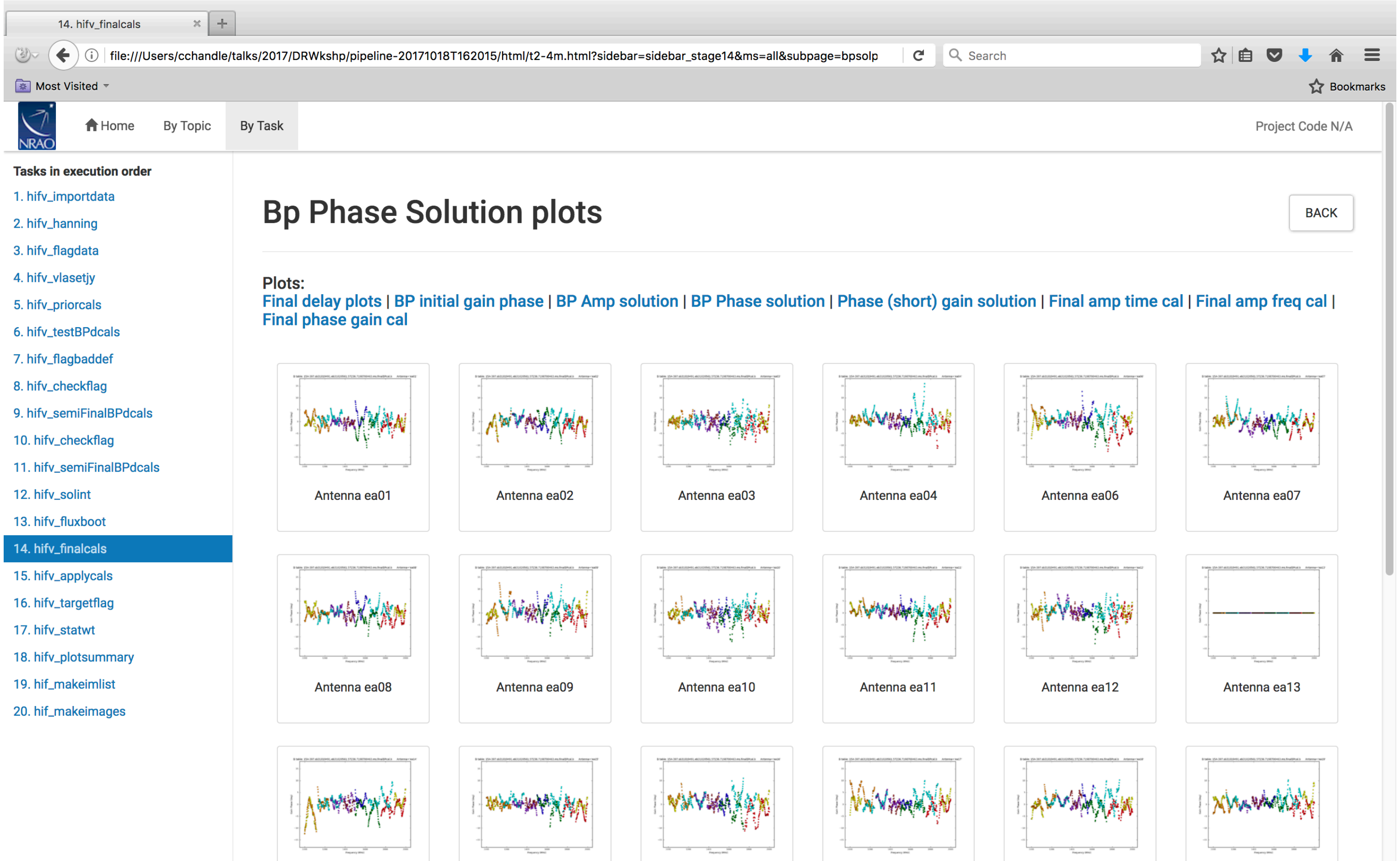
Final Cal Tables: bandpass



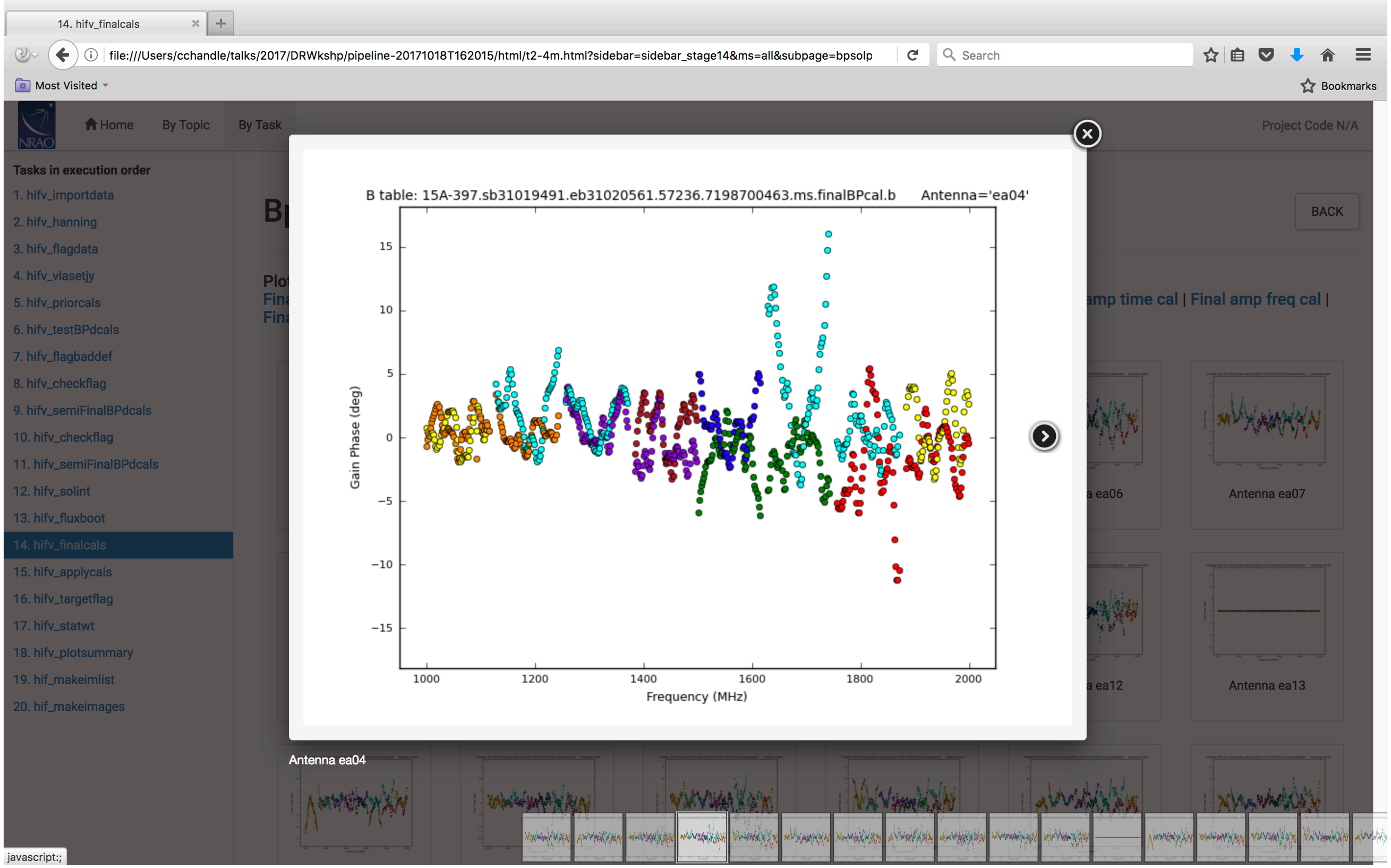
Final Cal Tables: bandpass



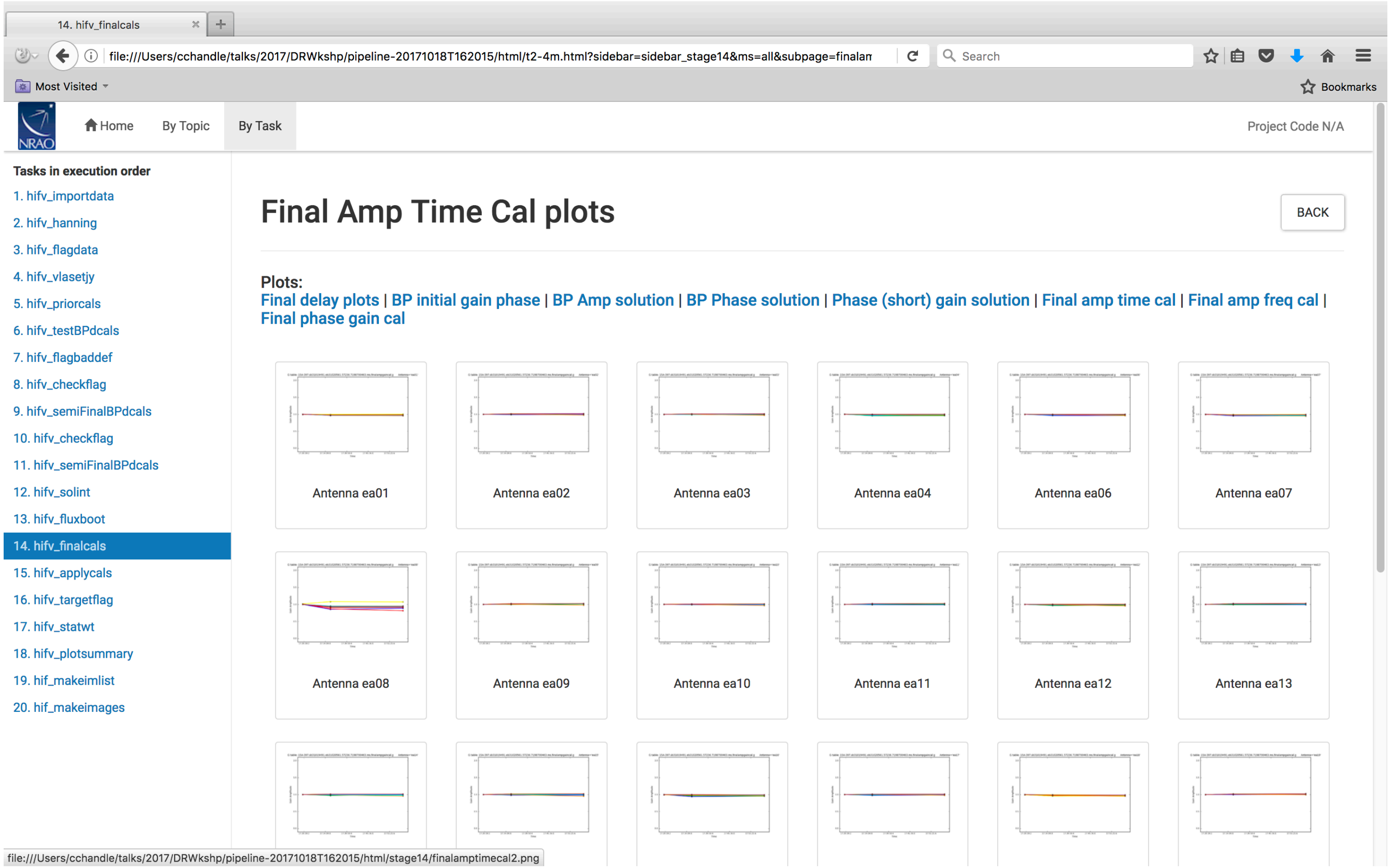
Final Cal Tables: bandpass



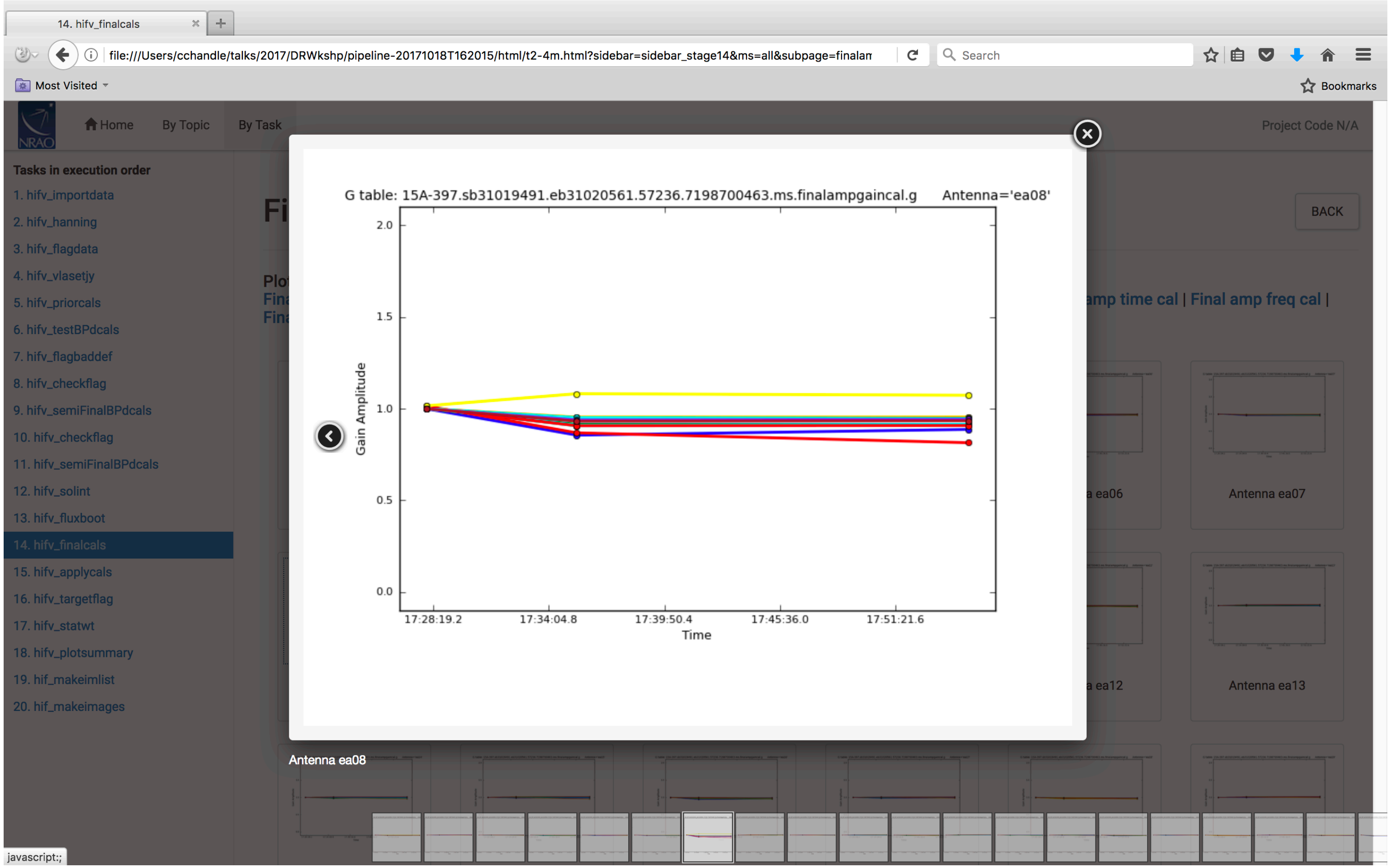
Final Cal Tables: bandpass



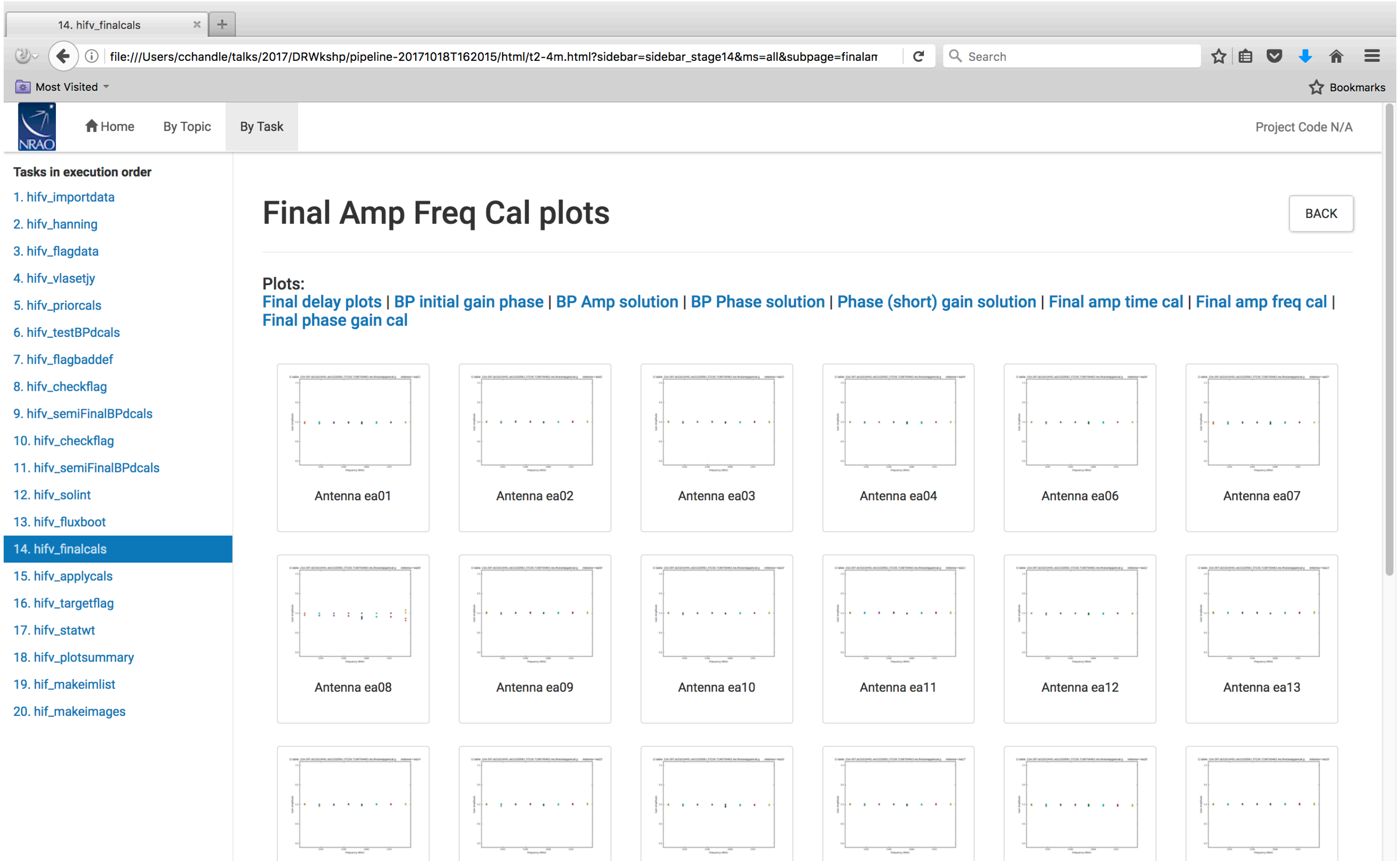
Final Cal Tables: amplitude



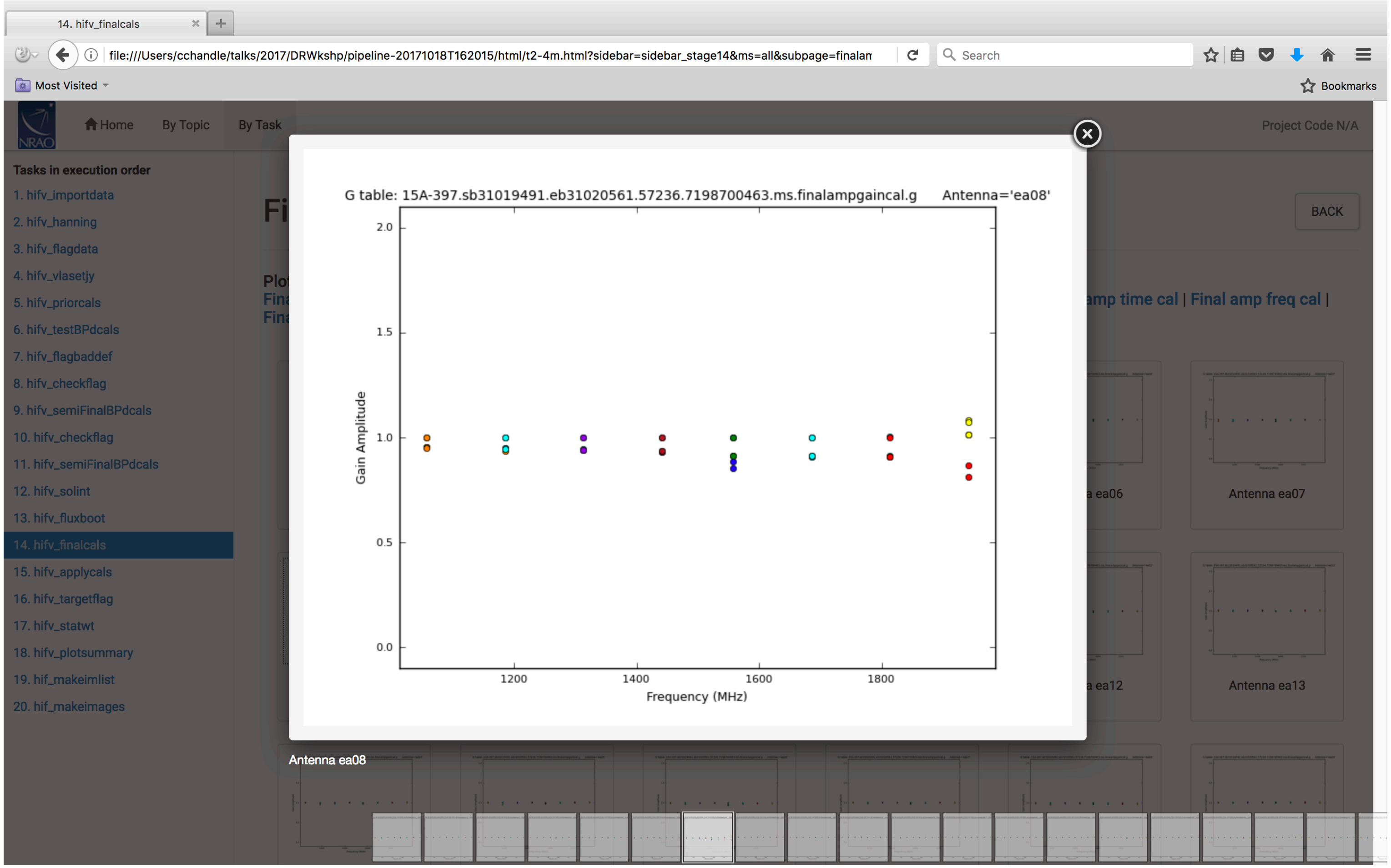
Final Cal Tables: amplitude



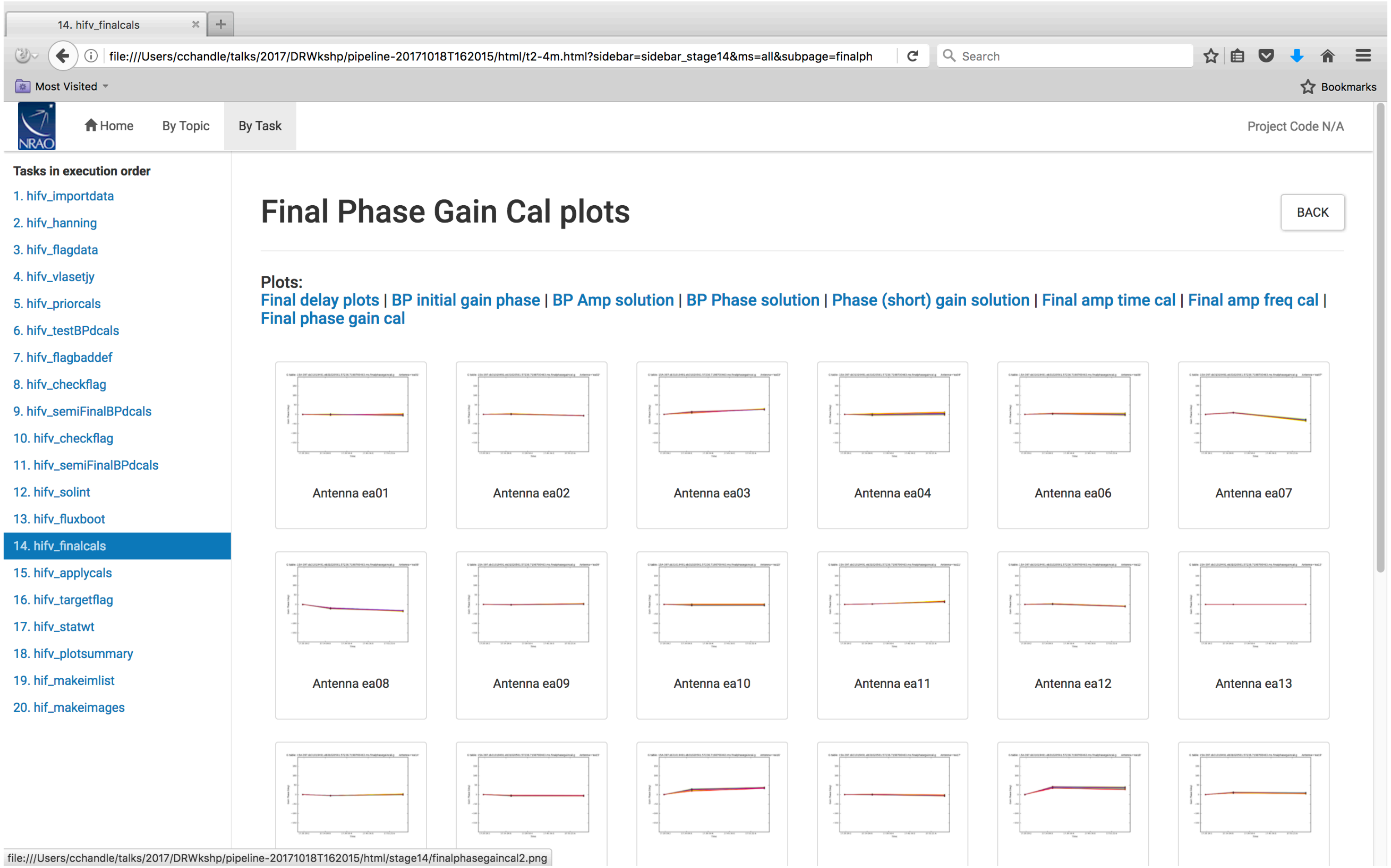
Final Cal Tables: amplitude



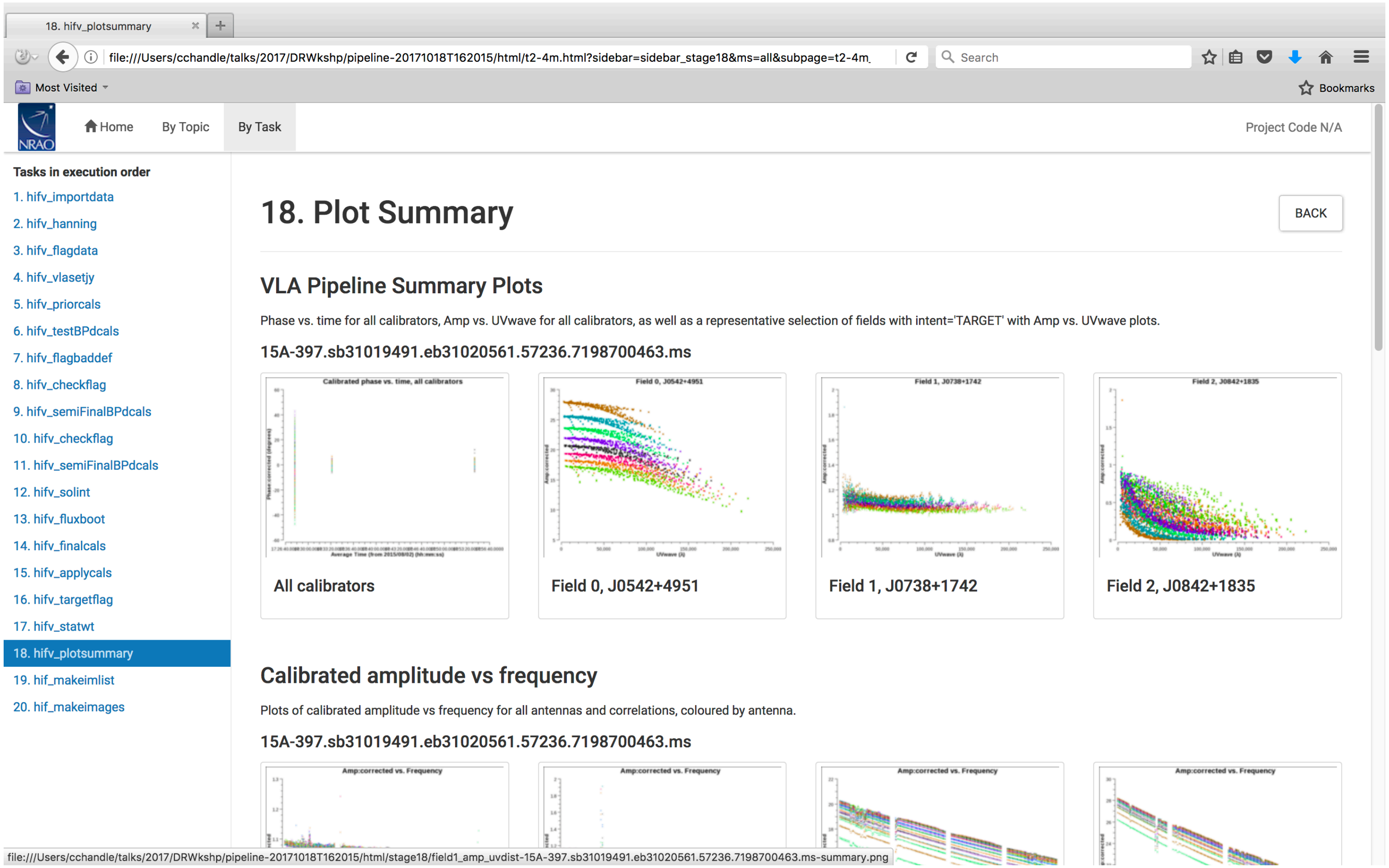
Final Cal Tables: amplitude



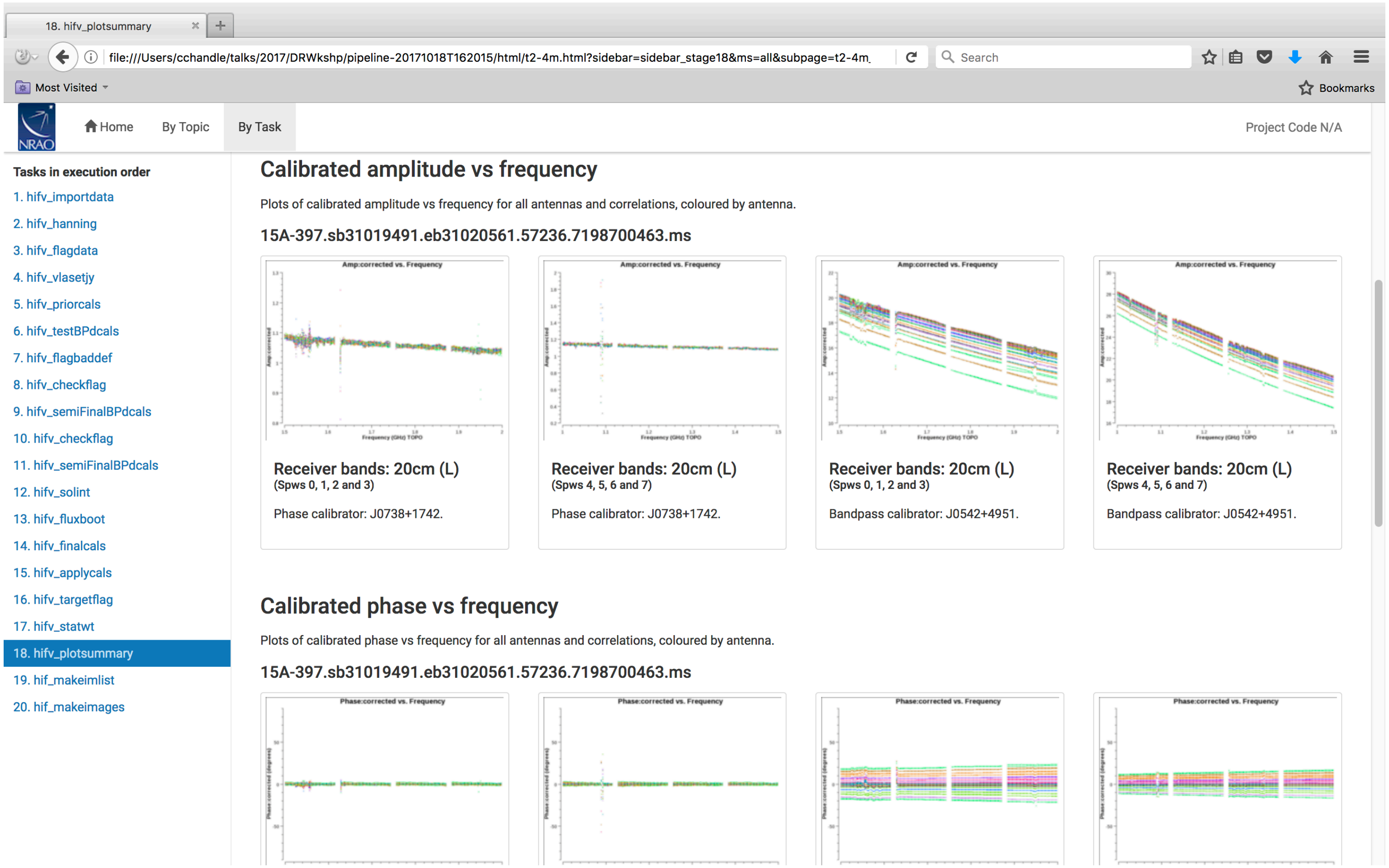
Final Cal Tables: phase



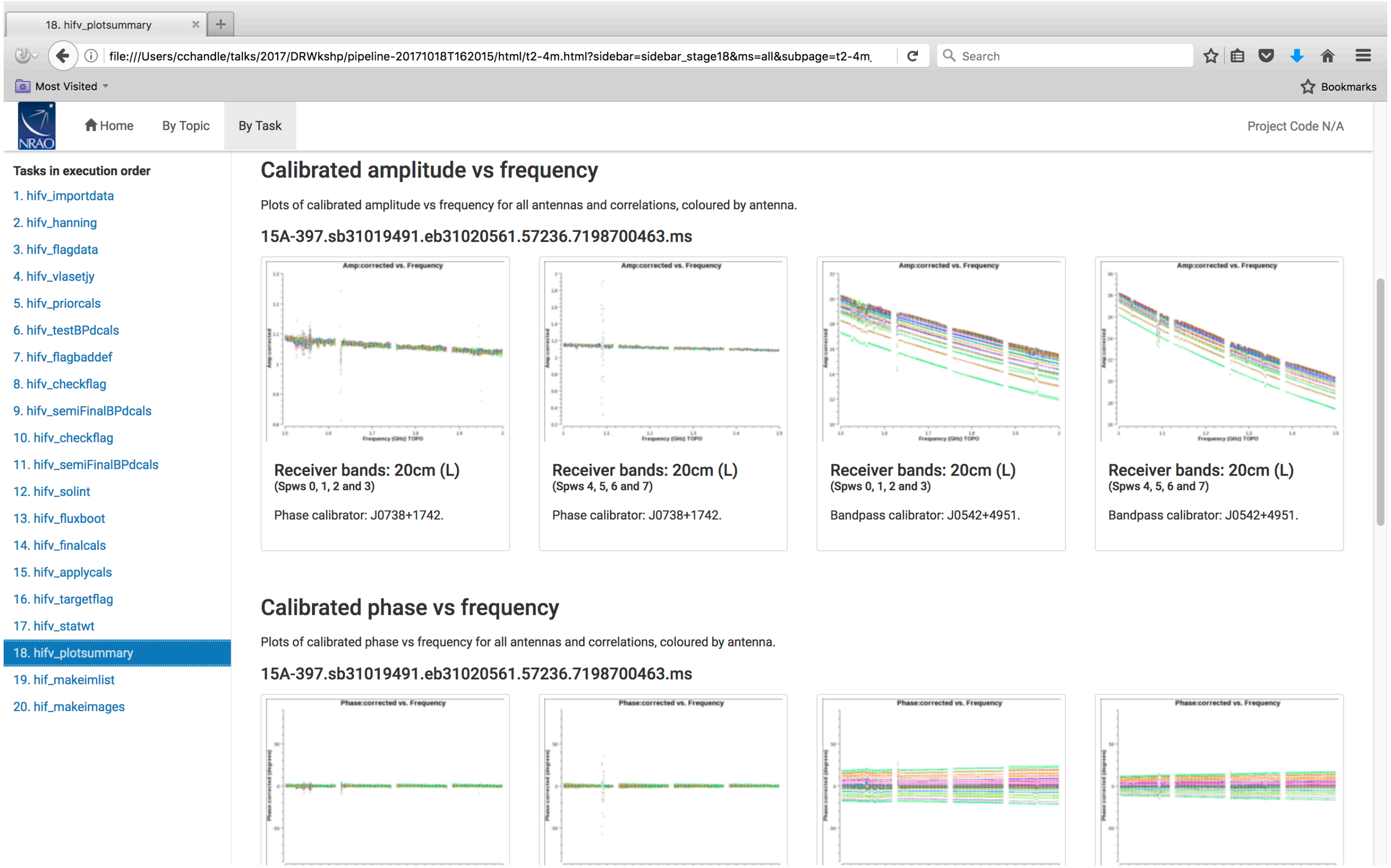
Summary Plots (hifv_plotsummary)



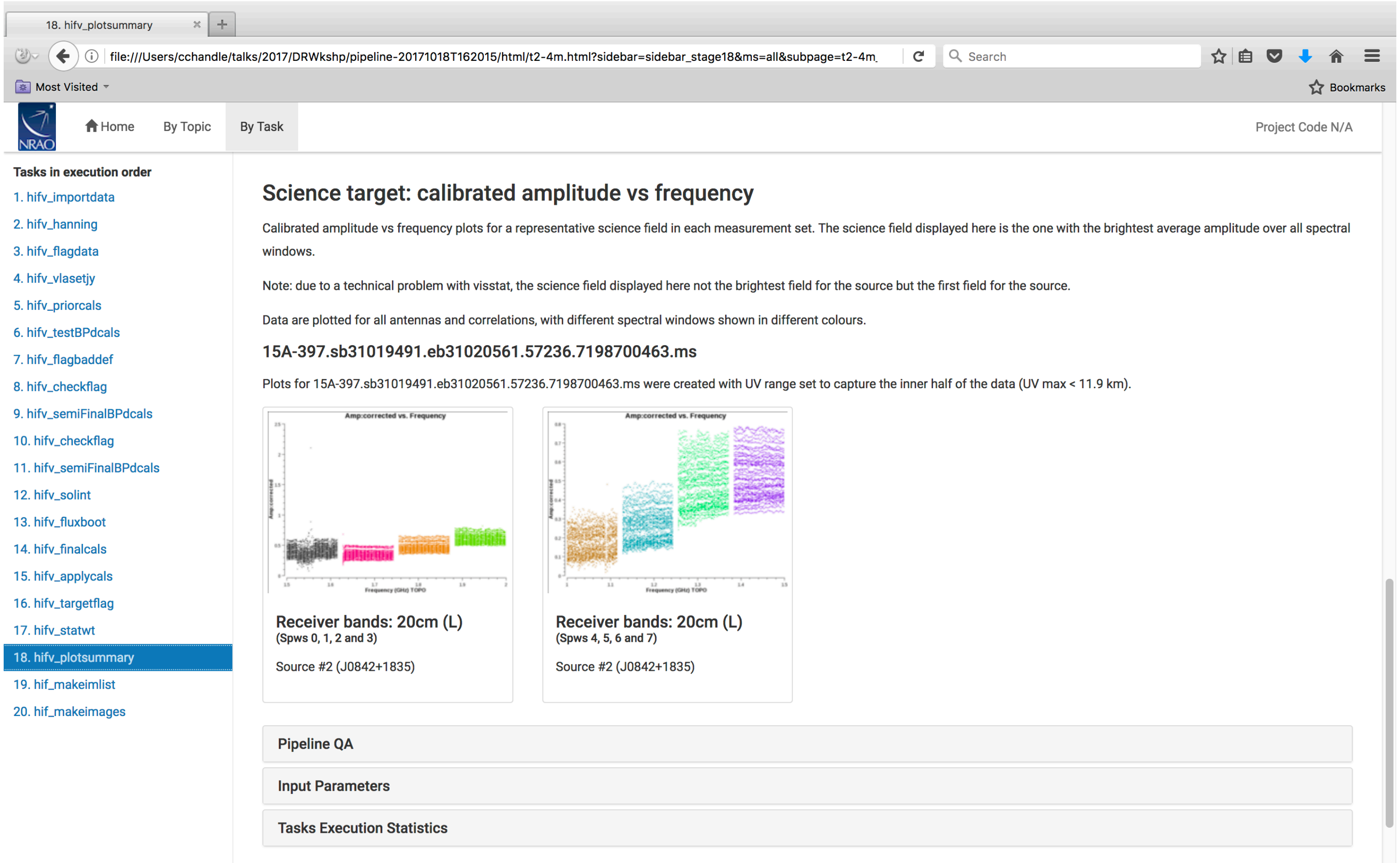
Summary Plots (hifv_plotsummary)



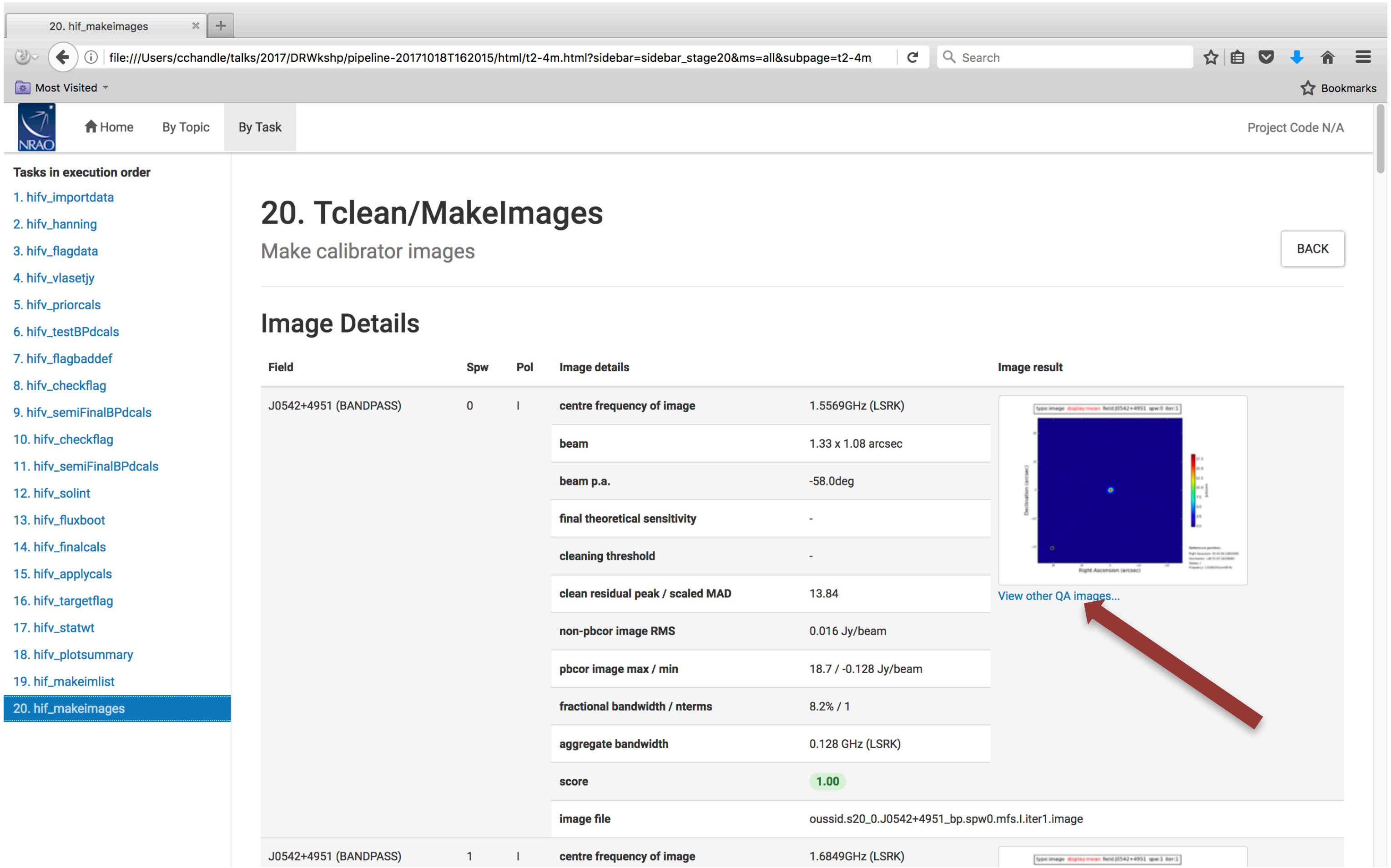
Summary Plots (hifv_plotsummary)



Summary Plots (hifv_plotsummary)



Calibrator Images (hif_makeimages)



Calibrator Images (hif_makeimages)

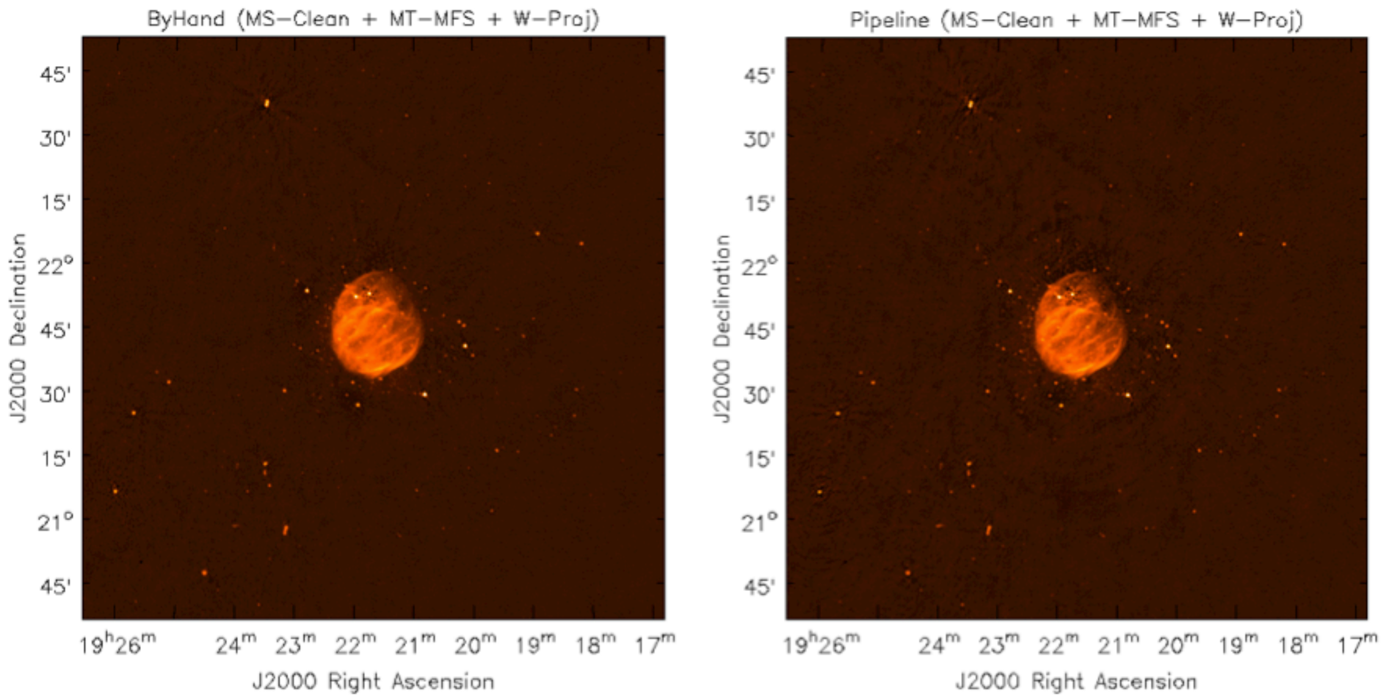
Pipeline Products and Outputs

- Real-time pipeline products and output
  - Flag and calibration tables
  - Calibrated and flagged MS (available for 15 days, not archived)
  - Logs, including weblog used by quality assurance (QA) staff and QA report if requested
  - Products can be requested through the helpdesk (https://help.nrao.edu, VLA Pipeline Department), for download via FTP or shipping on hard disk(s)
- You may request a detailed QA report from the data analysts
- If you are happy with the pipeline calibration, then:
  - Do further flagging if necessary
  - Split out your target and image

Pipeline Products and Outputs

- If you have the SDM or uncalibrated MS and the calibration and flag tables, instructions for applying flags and calibration tables may be found at http://go.nrao.edu/vla-pipe; *see Drew's talk!*
- In some cases the pipeline and/or the MS may need to be modified
  - Download the SDM from the archive plus pipeline scripts
  - Follow the directions at above link
- In some cases the pipeline heuristics may not be appropriate for your data (e.g., some L-band set-ups do not work well with the pipeline yet)
  - Reduce data by hand

Imaging comparison



Left: L-band image of G55.7+3.4 produced from data flagged and calibrated by hand; the rms noise is 11.5 μJy/beam. Right: an image made from data flagged and calibrated by the VLA calibration pipeline; the rms noise is 12.2 μJy/beam. Differences in the source structure and/or source flux density are dominated by the uncertainty in the deconvolution process, not the calibration and flagging (images provided by Urvashi Rao).

Known failure modes and issues

- In general the pipeline does very well, but there are possible failure modes:
  - No flux density or gain calibrator intents defined, or flux density calibrator not one for which we have models
    - *work around in scripted pipeline*
  - Wrong scan intents
    - *work around in scripted pipeline*
  - Does not always identify deformatter problems (but does NOT usually have false positives – L-band may be an exception)
    - *flag remaining bad spws*
  - Calibrators are too weak for given spw bandwidth
    - *heuristics have been developed for the case of a weak bandpass calibrator, you are welcome to try them on your data!*

Spectral line data

- Several steps in the real-time pipeline may not be appropriate for spectral line data:
  - Hanning smoothing (increases effective channel width)
  - Last run of RFLAG on target (may eliminate your line as interference!)
  - Statwt calculates rms based on scatter of channels per spw, per visibility; may want to run manually with channel selection turned on to eliminate use of channels containing line emission in calculating the rms
- With the above modifications, the pipeline will work with spectral line data as long as the calibrators are strong enough

Mixed correlator set-ups

- With the new WIDAR capabilities it is common to observe both wide and narrow spws to obtain both continuum and spectral line data simultaneously, or multiple receiver bands
  - A single heuristic (e.g., gain calibration solution interval) for entire dataset may not be appropriate
- Solution:
  - Run pipeline through application of deterministic flags, including Hanning smoothing if you are going to use it
  - Split the MS by spw and/or scans
  - Run pipeline on split MSs WITHOUT Hanning smoothing (you have already applied it, if you are going to use it)
  - Warning: output flagging statistics may not be correct

Special cases

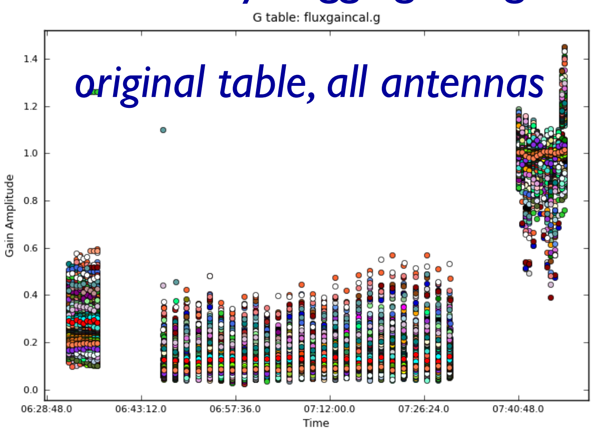
- Incorrect scan intents
  - Best to use the scripted pipeline (otherwise have to edit SDM)
  - Can run through msinfo.py, then re-set the following string variables to refer to the correct scan and field IDs:

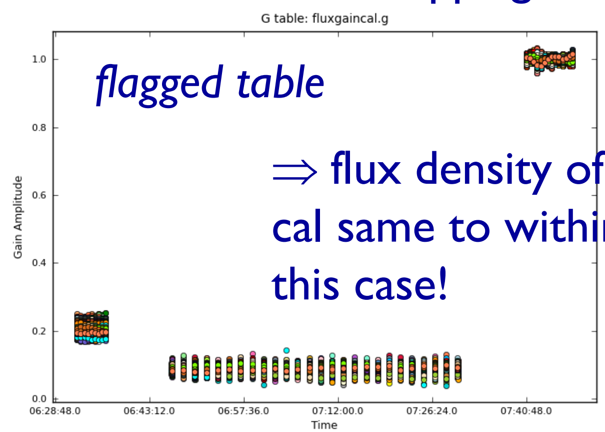
```
flux_field_select_string='2'
bandpass_scan_select_string='8'
bandpass_field_select_string='4'
delay_scan_select_string='8'
delay_field_select_string='4'
calibrator_scan_select_string='4,5,7,8,10,11,12'
calibrator_field_select_string='1,2,3,4,5,6,7'
phase_scan_list=[1,3,5,7,9,11,13,15]
```

- If a standard flux density calibrator was not observed, you may still be able to use the pipeline IF you know the flux density and spectral index of one of your other calibrators, with a bit more work – contact the NRAO helpdesk

Special cases

- Accurate flux density bootstrapping
  - hifv_fluxboot uses medians to bootstrap flux densities: fairly robust, but in some cases (e.g., high frequencies with pointing, elevation dependent gains) you can do better by flagging the gain table used for the bootstrapping





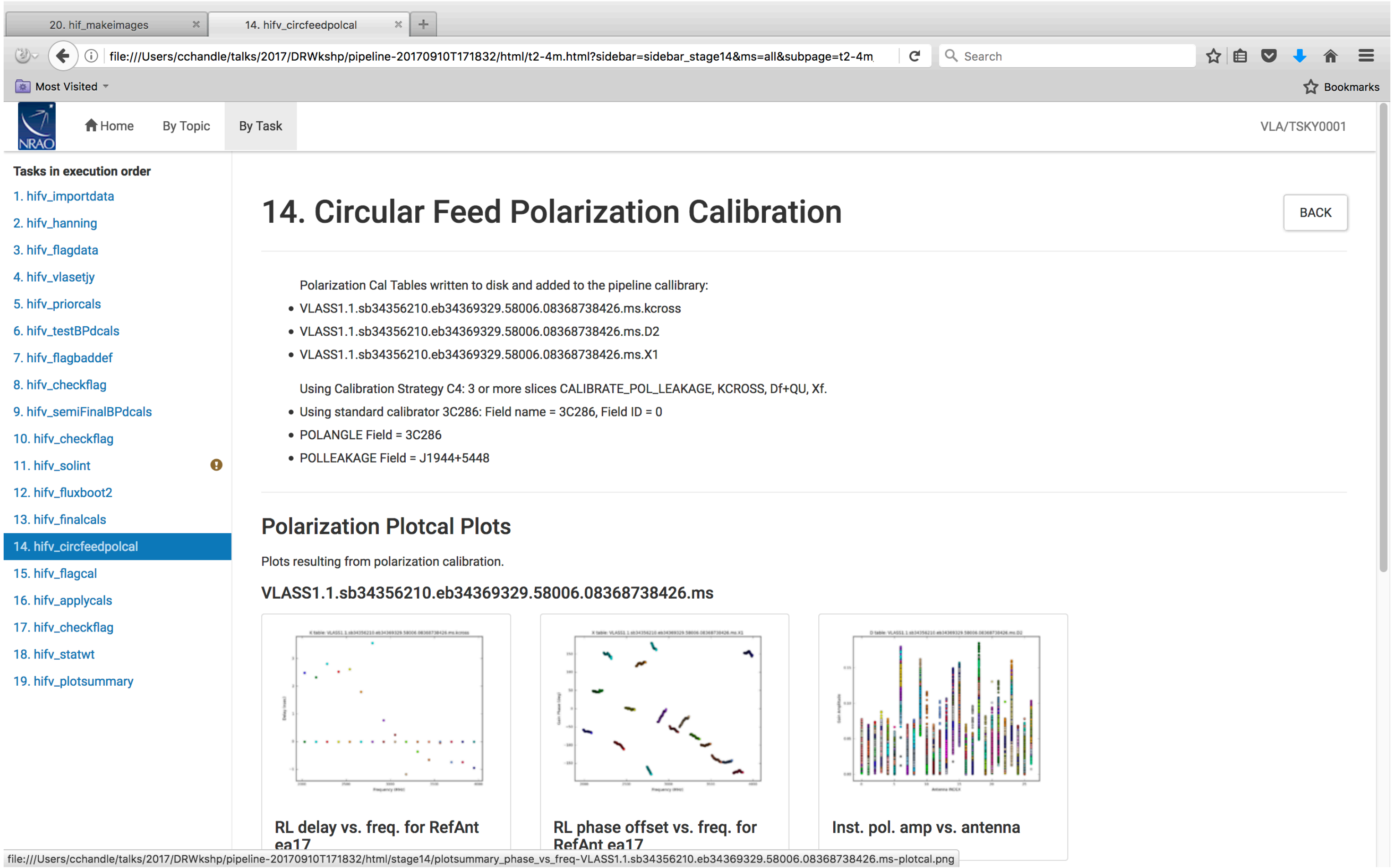
⇒ flux density of phase cal same to within 5% in this case!

  - Run pipeline through hifv_fluxboot
  - In a separate instance of CASA, flag input gain table using "plotcal" or "plotms"
  - Re-run hifv_fluxboot specifying name of input gain table, then continue with the rest of the pipeline
  - With care (match elevation of flux cal, flag bad data), can reproduce flux density scale to a few % at Q-band

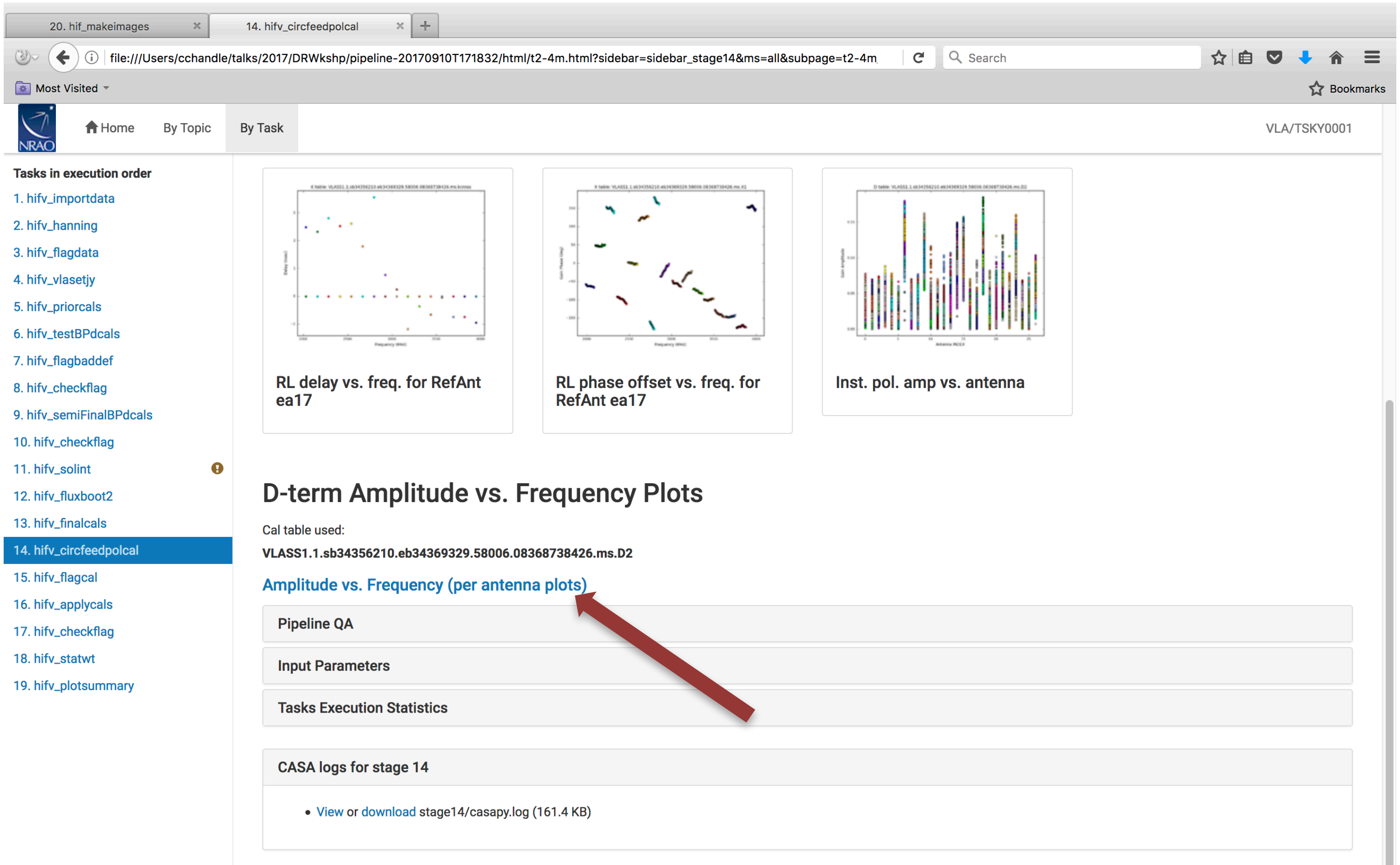
Summary and VLASS Developments

- Heuristics for Stokes I continuum now well-tested, stable, minor modifications allow the pipeline to be used for certain spectroscopy projects as well
- Heuristics available for user-testing:
  - Weak bandpass calibrators
- Development for the VLA Sky Survey available for user-testing:
  - Improved RFI flagging
    - Uses cross-hands to help identify and flag RFI
  - More robust flux density bootstrapping (single-band only)
    - Flags input data to remove bad solutions before fitting
  - Polarization calibration
    - Makes some assumptions about calibrator strengths
    - Supports unpolarized and unknown polarization leakage calibrators
- [VLASS imaging pipeline, specific to VLASS observing mode]

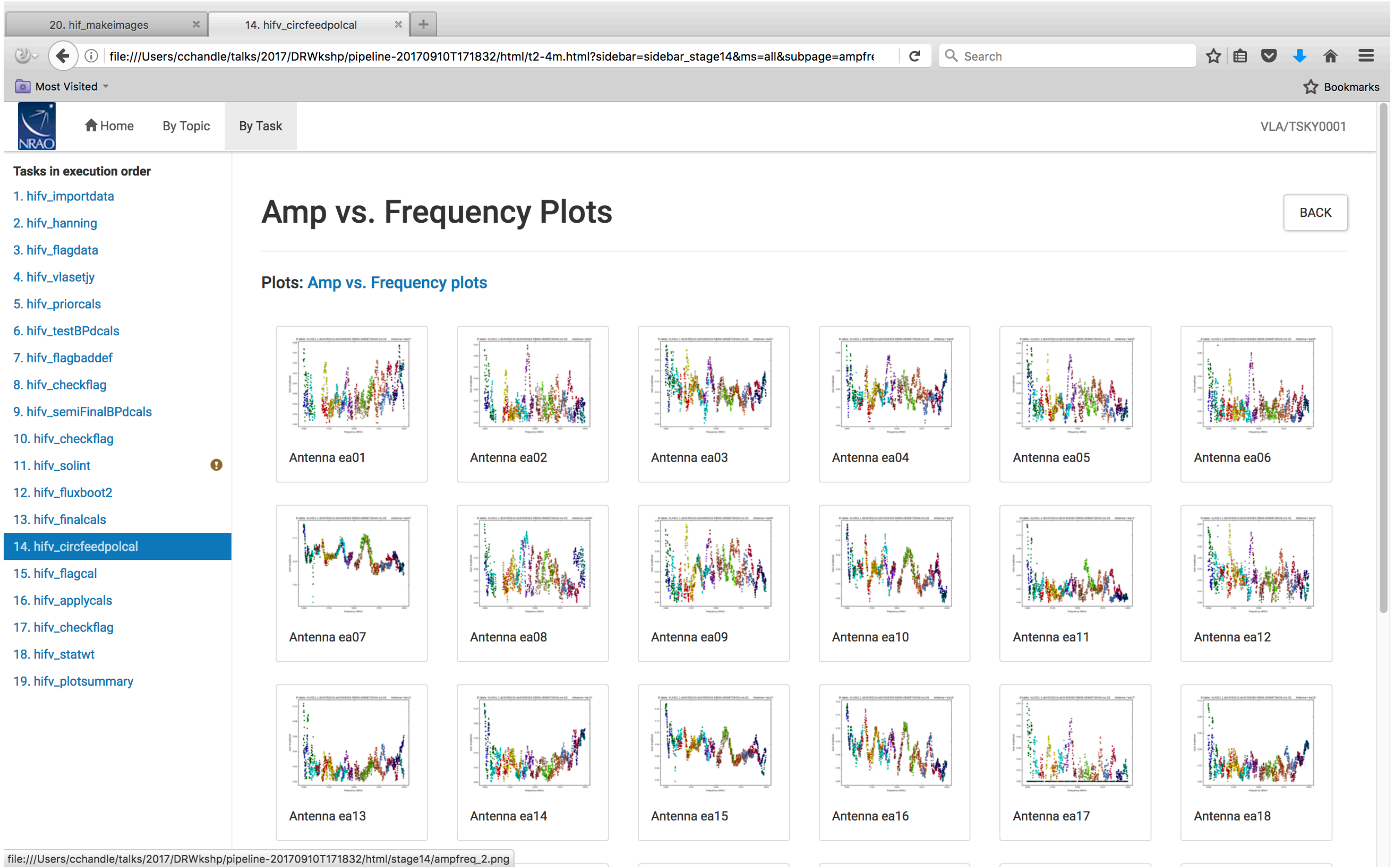
Polarization Calibration (hifv_circfeedpolcal)



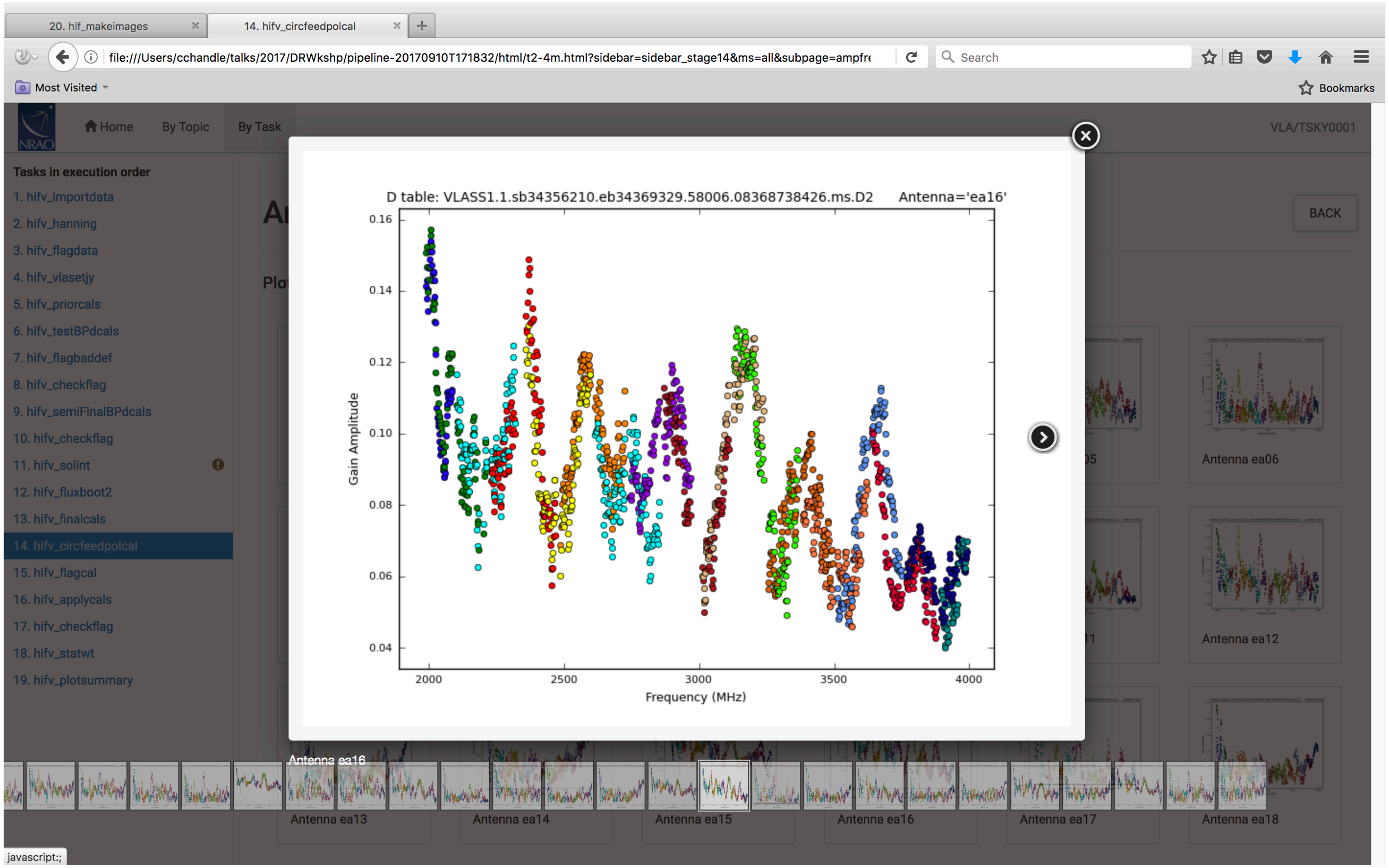
Polarization Calibration (hifv_circfeedpolcal)



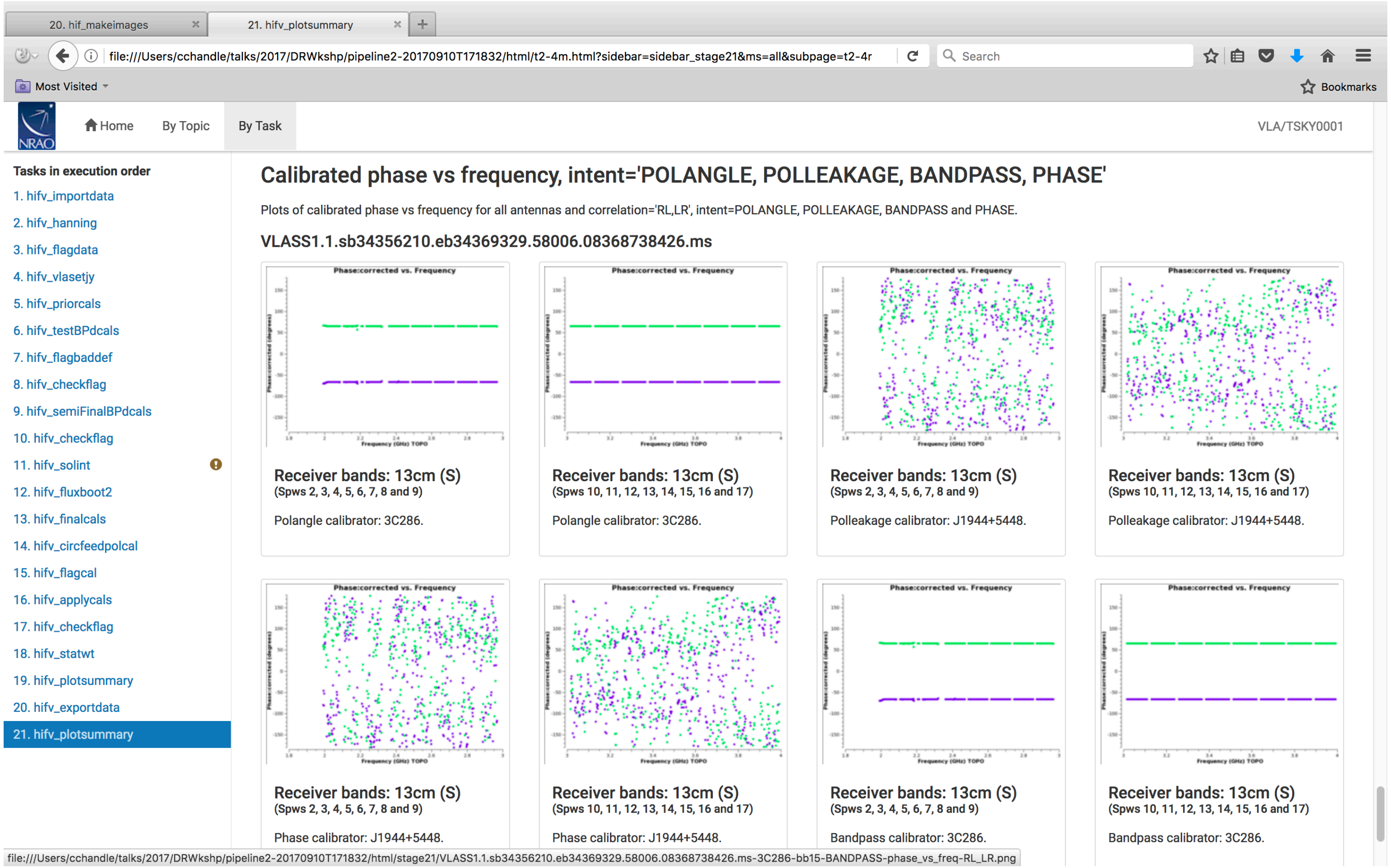
Polarization Calibration (hifv_circfeedpolcal)



Polarization Calibration (hifv_circfeedpolcal)



Additional polcal plotsummary plots



Future Developments

- Heuristics being developed for:
  - Multi-band delays
  - Gain compression
  - Low-frequencies (<1GHz)
  - Self-calibration and imaging for PI science
- Heuristics developed in consultation with expert users and staff; testing, feedback, suggestions welcome!

For how to run the pipeline see Drew's talk next! Or go to http://go.nrao.edu/vla-pipe