ezRA - Easy Radio Astronomy - ezCon

- Nov-18-2022

ezRA - Easy Radio Astronomy
https://github.com/tedcline/ezRA

The ezCon program is a data CONdenser, which reads one or more frequency spectrum data .txt files, processes the data to better reveal the Galactic hydrogen information, and creates one condensed data .ezb file, and perhaps one Galaxy data *Gal.npz file. Along the way, ezCon creates many plot image files and perhaps 2 text files to study.

.ezb Data File Column Numbering

That human-readable .ezb condensed data output file has a few header lines, followed by one long line for each recorded data sample. Each long line has 20 ragged columns of numbers, separated by one space character.

The "coordinate" columns 0 through 9 are unrelated to the radio of the sample:
TimeUtcMjd, RAH, DecDeg, GLatDeg, GLonDeg, VLSR, Count, Spare1, Spare2

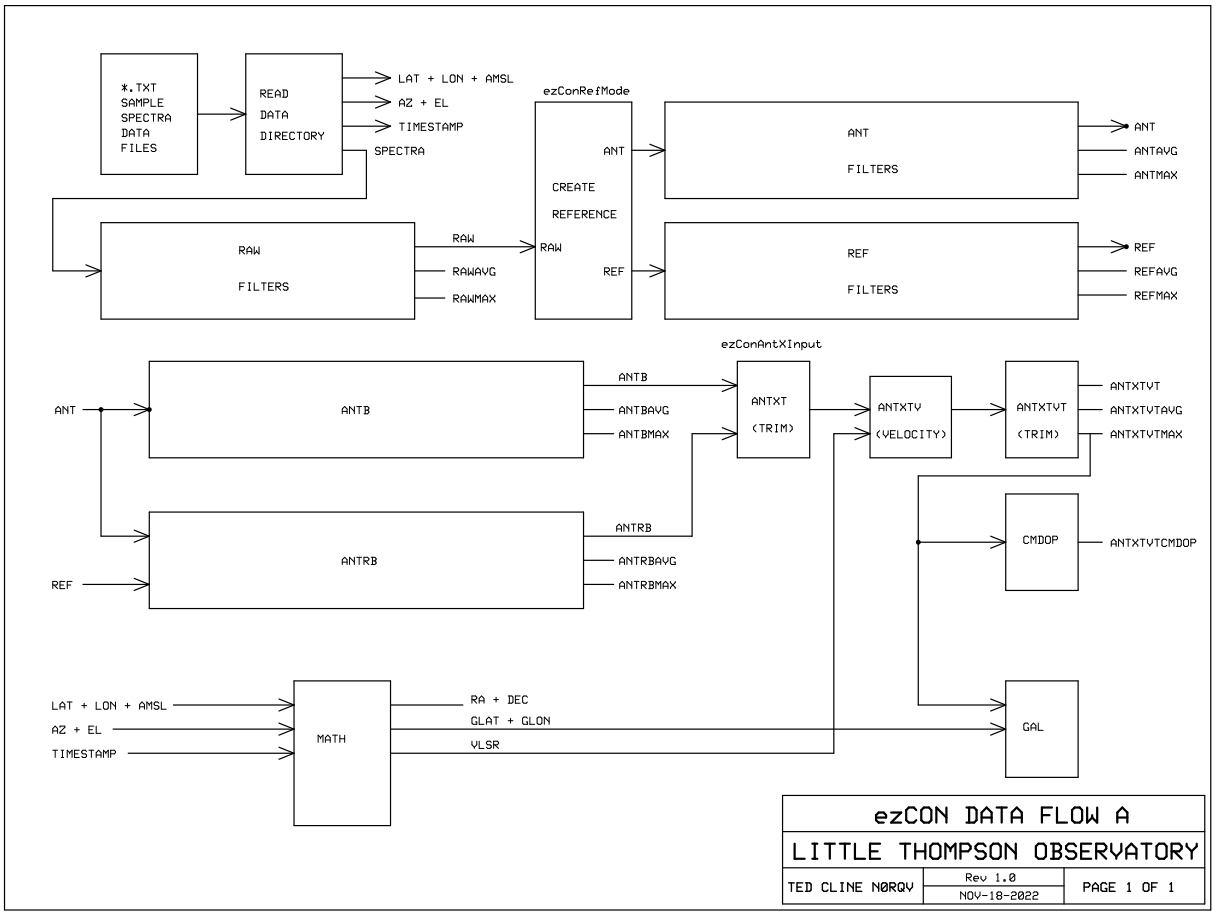
Spare1 and Spare2 are experimentally redefined as Azimuth and Elevation.

The remaining 11 "signal" columns document the processing of the radio samples. The last 10 "signal" columns are 5 signal pairs of the signal sample's average value, followed by its signal sample's maximum value. The 2 unprocessed (maybe filtered) signals are in columns 10 through 13:
AntAvg, AntMax, RefAvg, RefMax
The 3 processed signals are in columns 14 through 19:
AntBAvg, AntBMax, AntRBAvg, AntRBMax, AntXTVTAvg, AntXTVTMax
Throughout ezRA, these 10 signals use this order, and are conveniently numbered using 0 through 9. Each of the 5 signals use its own color for plot traces.

And then there is column 9 with the unusual processed signal, AntXTVTCmDop, which tracks the center-of-mass of the Doppler shift of the AntXTVT signal.

ezCon Data Flow

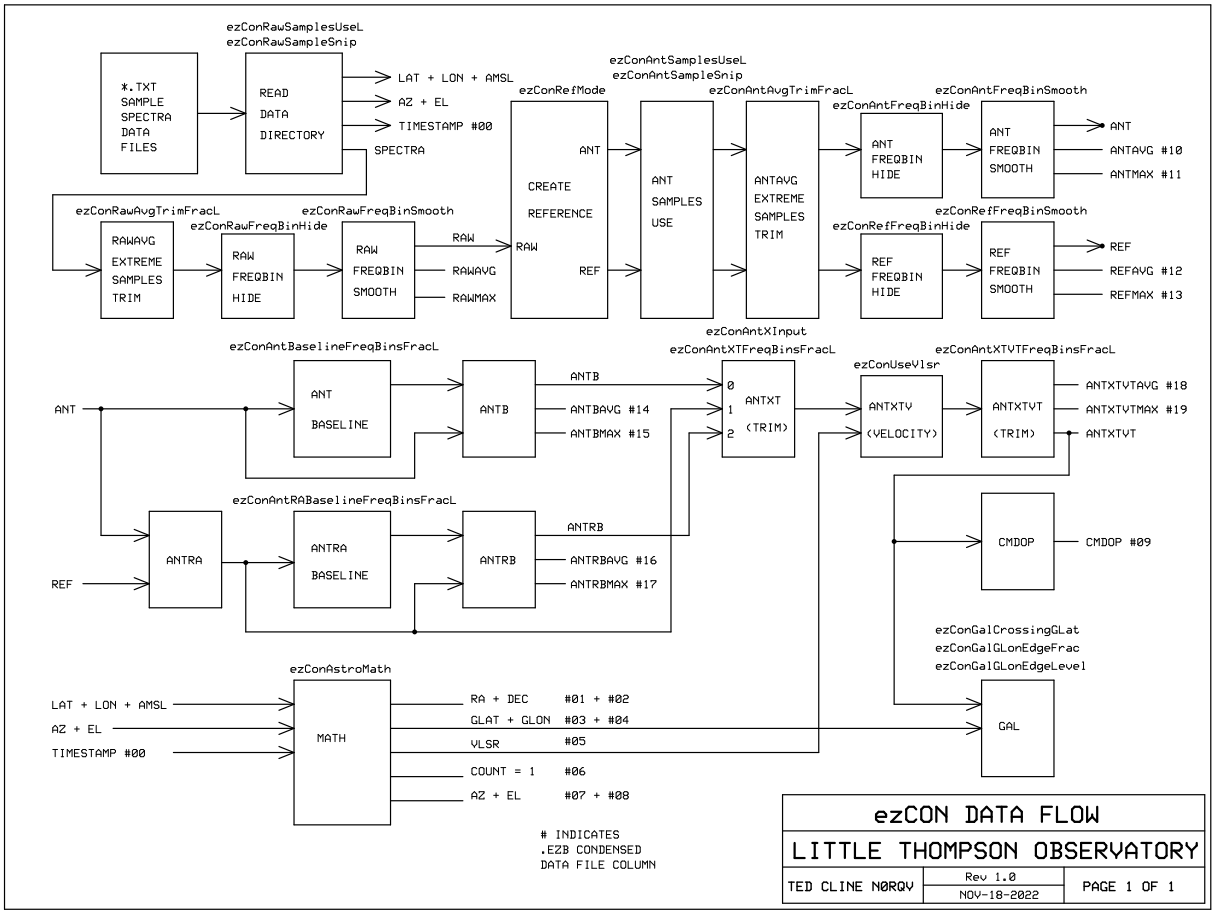
Here is simplified diagram of the data flow inside the ezCon program.



Starting at the top left, ezCon reads .txt data files, filters the Raw data samples, and separates them into Antenna (Ant) samples and Reference (Ref) samples.

Continuing at center left, ezCon uses those Ant and Ref samples to create the AntB and AntRB signals. It then selects AntB (default) or AntRB, and creates AntXT, AntXTV, and AntXTVT signals. All to better reveal Galactic hydrogen emission and the information it contains. Default values for the many options provide guidance.

Here is a more complete diagram of the data flow inside the ezCon program.



This ezCon program diagram reveals more program controls, and the output .ezb file column numbers.

ezCon Plot File List

Each ezCon plot image filename starts with “ezCon”, followed by a 3-digit number, followed by a brief description, followed by “.png” . The first plot filename is “ezCon001raw.png”.

The ezCon plot files are organized into groups. The groupings allows the -ezConPlotRangeL arguments to speed execution by creating only the related plots that are wanted.

The ezCon0Nx plot files are colorful heatmaps of frequency spectra, using color to indicate relative power values, where N is the 0-9 signal number (plotting sample spectrum frequency by sample number). The Max plots also mark each vertical sample’s maximum value with a green dot, and mark the maximum value of those maximums with a yellow dot. Ideally, those green maximum dots track the weak hydrogen signal, but sometimes they mark stronger noise.

ezCon001raw.png	- filtered Raw sample spectra, Ant and Ref mingled
ezCon002antRaw.png	- unfiltered Ant sample spectra
ezCon007ant.png	- filtered Ant sample spectra
ezCon017antMax.png	- filtered Ant sample spectra, with dots on spectrum maximum
ezCon027ref.png	- filtered Ref sample spectra
ezCon037refMax.png	- filtered Ref sample spectra, with dots on spectrum maximum
ezCon047antB.png	- AntB sample spectra
ezCon057antBMax.png	- AntB sample spectra, with dots on spectrum maximum
ezCon061antRA.png	- AntRA sample spectra (calculation step toward AntRB)
ezCon067antRB.png	- AntRB sample spectra
ezCon077antRBMax.png	- AntRB sample spectra, with dots on spectrum maximum
ezCon081antXT.png	- AntXT (from AntB, AntRA, or AntRB) spectra, freq Trimmed
ezCon082antXTV.png	- AntXTV sample spectra, VLSR Velocity corrected
ezCon087antXTVT.png	- AntXTVT sample spectra, frequency Trimmed
ezCon097antXTVTMax.png	- AntXTVT sample spectra, with dots on spectrum maximum

The ezCon1NN plot files are 2-dimensional plots of values related to samples, where NN is generally the output condensed data .ezb file 0-19 column number (plotting value by sample number). These include coordinate values (such as time, declination, or VLSR), and signal values (such as Ant, Ref, or AntRB). Identify problem samples with the ezConStudy*.txt file, which records the samples that have the maximum, minimum, and greatest change values, for each of 10 signals.

ezCon100timeUtcMjd.png	- UTC MJD time of sample (fractional days)
ezCon101raH.png	- Right Ascension of sample (hours)
ezCon102decDeg.png	- Declination of sample (degrees)
ezCon103gLatDeg.png	- Galactic Latitude of sample (degrees)
ezCon104gLonDeg.png	- Galactic Longitude of sample (degrees)
ezCon105vlsr.png	- VLSR of sample (km/sec)
ezCon110antAvg.png	- filtered Ant averaged spectrum values
ezCon111antMax.png	- filtered Ant maximum spectrum values
ezCon112refAvg.png	- filtered Ref averaged spectrum values
ezCon113refMax.png	- filtered Ref maximum spectrum values
ezCon114antBAvg.png	- AntB averaged spectrum values
ezCon115antBMax.png	- AntB maximum spectrum values
ezCon116antRBAvg.png	- AntRB averaged spectrum values
ezCon117antRBMax.png	- AntRB maximum spectrum values
ezCon118antXTVTAvg.png	- AntXTVT averaged spectrum values
ezCon119antXTVTMax.png	- AntXTVT maximum spectrum values
ezCon191sigProg.png	- summary of ezCon110-ezCon119 plots
ezCon198azimuth.png	- Azimuth sample values (degrees)
ezCon199elevation.png	- Elevation sample values (degrees)
ezConStudy*.txt	- text max, min, and fastest-changing value, sample number, for 10 signals

The ezCon2Nx plot files are 2-dimensional plots of values related to samples, revealing the processing of the Galactic hydrogen information, where N is generally the output condensed data .ezb file 0-19 column number (plotting value by sample number). These include raw, separated, and processed data (such as time between Raw or Ant samples, Ant, Ref, AntRA, AntXT). Some of these ezCon2xx plots present the same information as some of the ezCon1xx plot files.

ezCon201ArawAvg.png - unfiltered Raw spectrum average values
ezCon201GrawAntRef.png - unfiltered Raw spectrum average values, with Ant and Ref dots

ezCon201HtimeUtcMjdDBetweenRaw.png - time between Raw samples (seconds)
ezCon201ItimeUtcMjdDBetweenAnt.png - time between Ant samples (seconds)
ezCon201JtimeUtcMjdDBetweenRef.png - time between Ref samples (seconds)

ezCon202antRawAvg.png - unfiltered Ant spectrum average values
ezCon207antAvg.png - filtered Ant spectrum average values (like ezCon110)
ezCon217antMax.png - filtered Ant spectrum maximum values (like ezCon111)

ezCon227refAvg.png - filtered Ref spectrum average values (like ezCon112)
ezCon237refMax.png - filtered Ref spectrum maximum values (like ezCon113)

ezCon241antBaseline.png - AntBaseline values (calculation step toward AntB)
ezCon247antBAvg.png - AntB spectrum average values (like ezCon114)
ezCon257antBMax.png - AntB spectrum maximum values (like ezCon115)

ezCon261antRAAvg.png - AntRA spectrum average values (calculation step toward AntRB)
ezCon262antRABasAvg.png - AntRABas values (calculation step toward AntRB)
ezCon267antRBAvg.png - AntRB spectrum average values (like ezCon116)
ezCon277antRBMax.png - AntRB spectrum maximum values (like ezCon117)

ezCon281antXTAvg.png - AntXT spectrum average values, chosen and Trimmed
ezCon282antXTVAvg.png - AntXTV spectrum average values, VLSR Velocity corrected
ezCon287antXTVTAvg.png - AntXTVT spectrum average , freq Trimmed (like ezCon118)
ezCon297antXTVTMax.png - AntXTVT spectrum maximum values (like ezCon119)

The ezCon3Nx plot files are 2-dimensional plots of values by frequency, averaged or maximized across all samples, where N is generally the 0-9 signal number (plotting value by frequency). These include raw and separated and processed signal data (such as rawRaw, filtered Raw, Ant, Ref, AntRA, AntXT).

ezCon301rawByFreqBinAvg.png	- averaged Raw spectrum, Ant and Ref mingled
ezCon302antRawByFreqBinAvg.png	- averaged unfiltered Ant spectrum
ezCon307antByFreqBinAvg.png	- averaged filtered Ant spectrum
ezCon317antByFreqBinMax.png	- maximized filtered Ant spectrum
ezCon327refByFreqBinAvg.png	- averaged filtered Ref spectrum
ezCon337refByFreqBinAvg.png	- maximized filtered Ref spectrum
ezCon347antBByFreqBinAvg.png	- averaged AntB spectrum
ezCon357antBByFreqBinAvg.png	- maximized AntB spectrum
ezCon361antRAByFreqBinAvg.png	- averaged AntRA spectrum (step toward AntRB)
ezCon367antRBByFreqBinAvg.png	- averaged AntRB spectrum
ezCon377antRBByFreqBinMax.png	- maximized AntRB spectrum
ezCon381antXTByFreqBinAvg.png	- averaged AntXT spectrum
ezCon382antXTVByFreqBinAvg.png	- averaged AntXTV spectrum
ezCon387antXTVTByFreqBinAvg.png	- averaged AntXTVT spectrum
ezCon388antXTByFreqBinAvgRfi.png	- rotated ezCon387 to identify freqBin values
ezCon397antXTVTByFreqBinMax.png	- maximized AntXTVT spectrum

If the data includes Galactic plane crossings, the ezCon5xx plot files are various plots of Galactic plane hydrogen gas velocity information. Many ezCon590 plot files are possible, each displaying a spectrum for a particular 1-degree Galactic Longitude. The ezCon511velGLonCount.txt file is a scorecard of which 1-degree Galactic Longitude Galactic plane spectra are recorded.

ezCon510velGLon.png - Galactic crossing corrected spectra vs 1-degree GLongitude
ezCon511velGLonCount.png - Count of Galactic crossing spectra vs 1-degree GLongitude
ezCon511velGLonCount.txt - text Count of Galactic crossing spectra vs 1-degree GLongitude

ezCon520velGLonPolar.png - Galactic crossing corrected spectra vs GLongitude, Polar
ezCon521velGLonPolarCount.png - Count of Galactic crossing spectra vs GLongitude, Polar

ezCon530galDecGLon.png - count of Galactic crossings, Declination vs Galactic Longitude

ezCon541velGLonEdges.png - min and max freq of Galactic crossing spectrum vs Glongitude

ezCon550galRot.png - Galactic rotation speed vs Galactic radius

ezCon590gLonDegP180_*ByFreqBinAvg.png - spectrum for one Gal crossing at a 1-degree GLon

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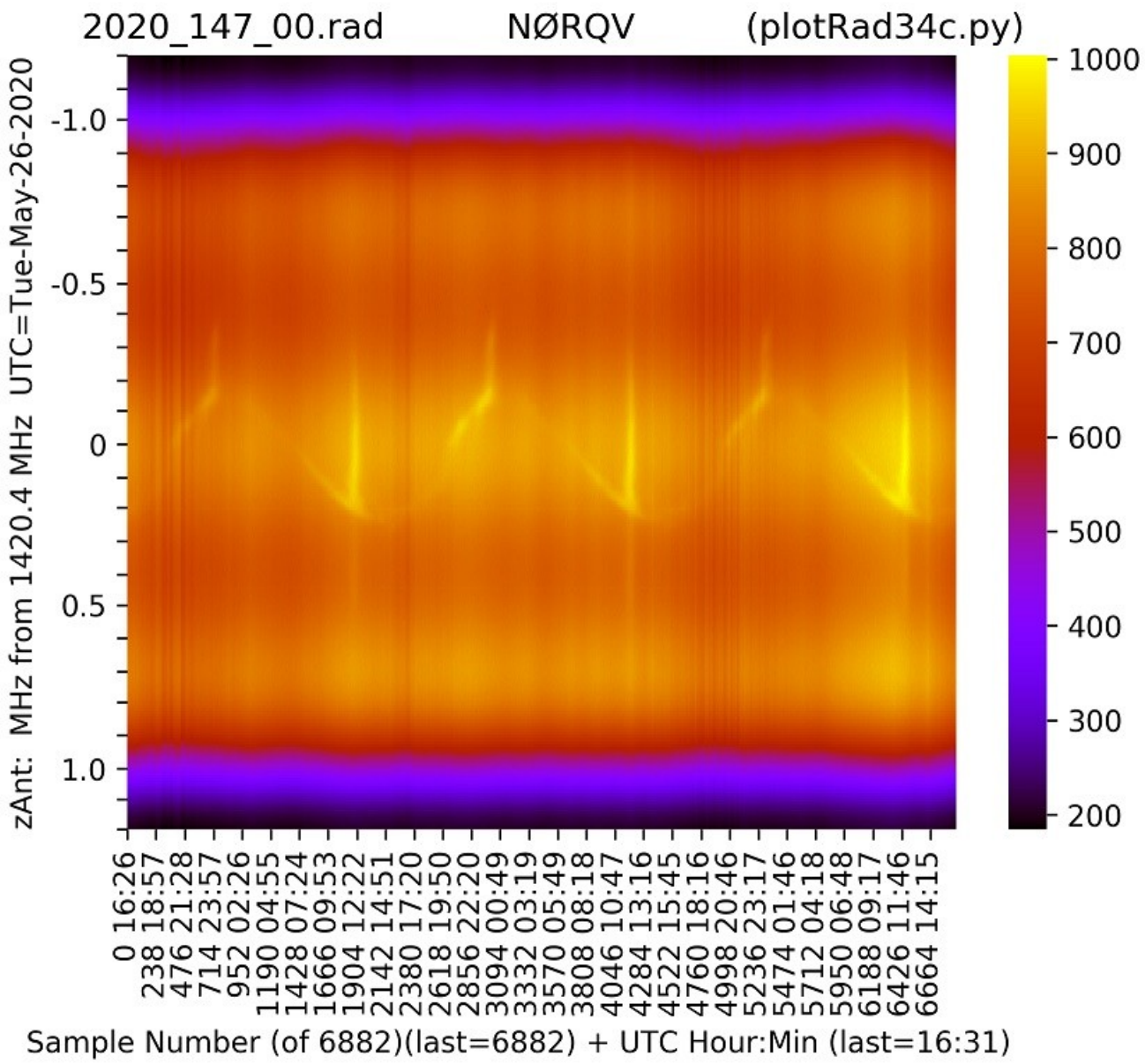
Blah, blah, blah …

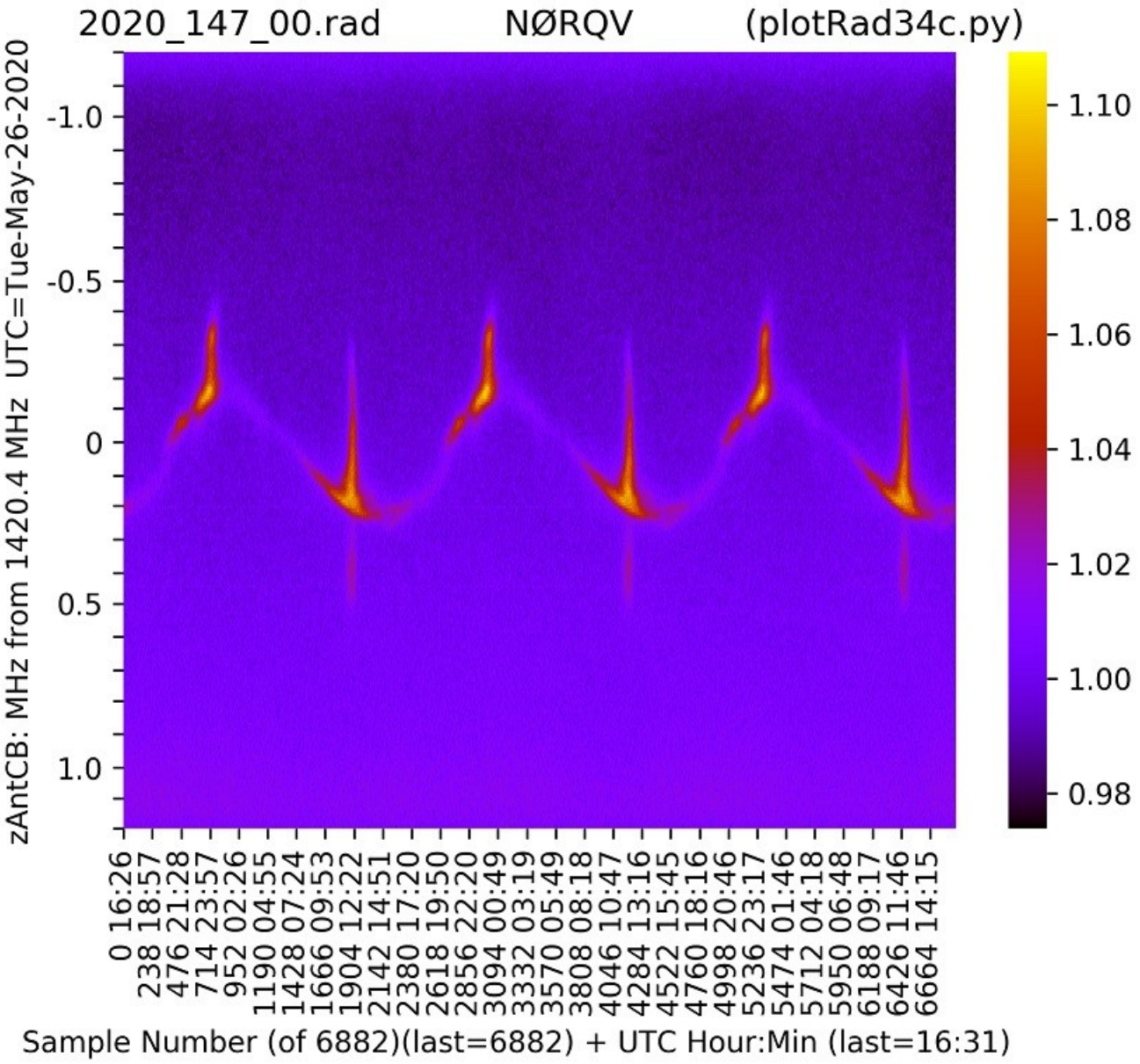
I continue exploring how to reduce the pesky day-to-day and minute-to-minute gain variation of our Radio Astronomy data.

My May-5-2020 “RA Status #15” talked about needing 3 inputs: Antenna signal, Calibrator signal, and local Temperature data. Within 3 hours of emailing that, I found I did not need the Temperature data.

My simpler system can record a noisy dish antenna signal,



and post-process it to something cleaner, with much less gain variation,

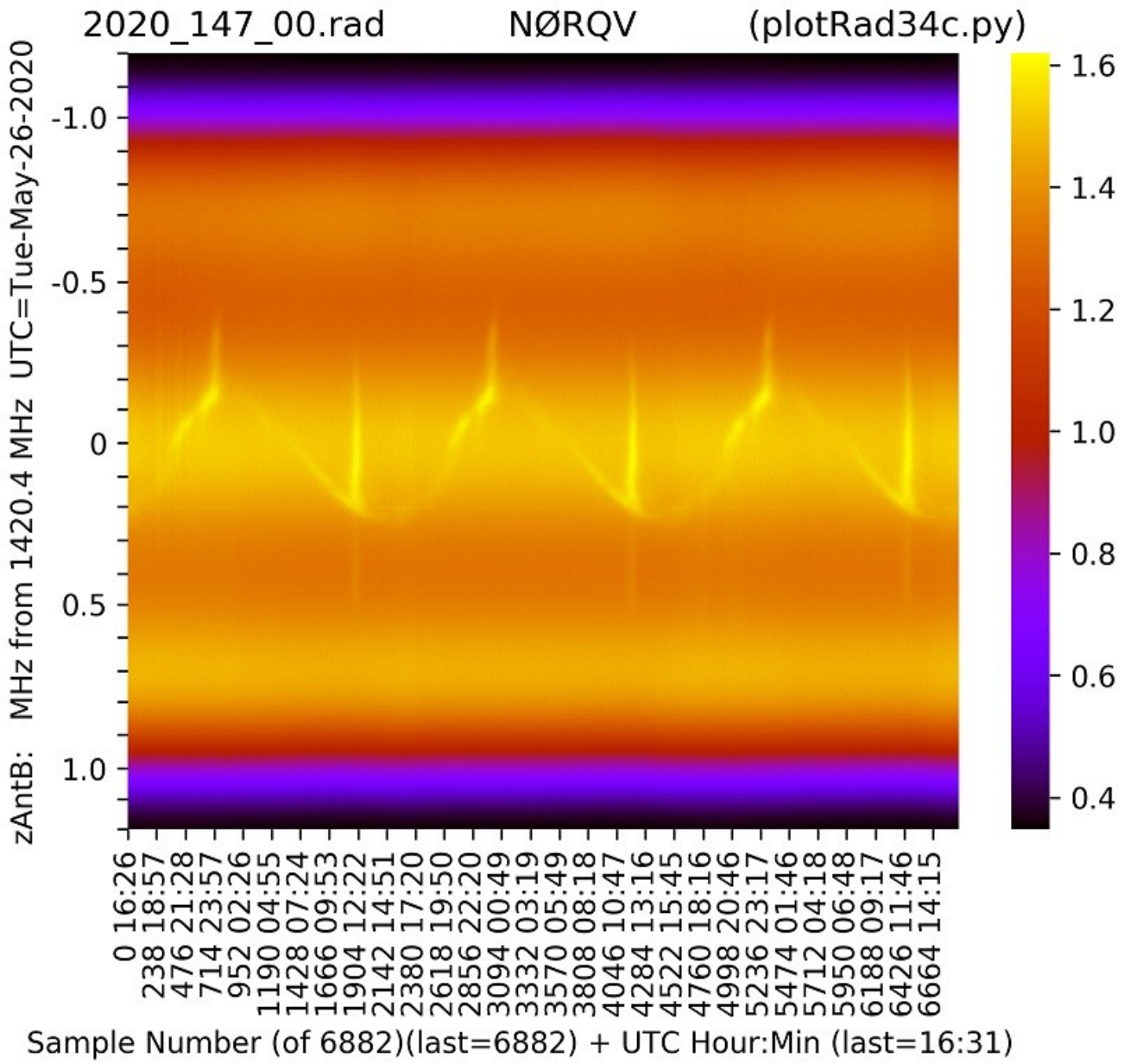

2020_147_00.rad
NØRQV
(plotRad34c.py)
zAntCB: MHz from 1420.4 MHz UTC=Tue-May-26-2020
-1.0
-0.5
0
0.5
1.0
1.10
1.08
1.06
1.04
1.02
1.00
0.98
0 16:26
238 18:57
476 21:28
714 23:57
952 02:26
1190 04:55
1428 07:24
1666 09:53
1904 12:22
2142 14:51
2380 17:20
2618 19:50
2856 22:20
3094 00:49
3332 03:19
3570 05:49
3808 08:18
4046 10:47
4284 13:16
4522 15:45
4760 18:16
4998 20:46
5236 23:17
5474 01:46
5712 04:18
5950 06:48
6188 09:17
6426 11:46
6664 14:15
Sample Number (of 6882)(last=6882) + UTC Hour:Min (last=16:31)

AntB

AntB is Ant minus the average of those dull (unused) top 60 Ant frequency bins and bottom 60 Ant frequency bins as a baseline in time.

AntB(f, t) = Ant(f, t) - AntBaseline(t)

AntB is interesting, but needs more processing,



Note how that removes the time (horizontal) variability.

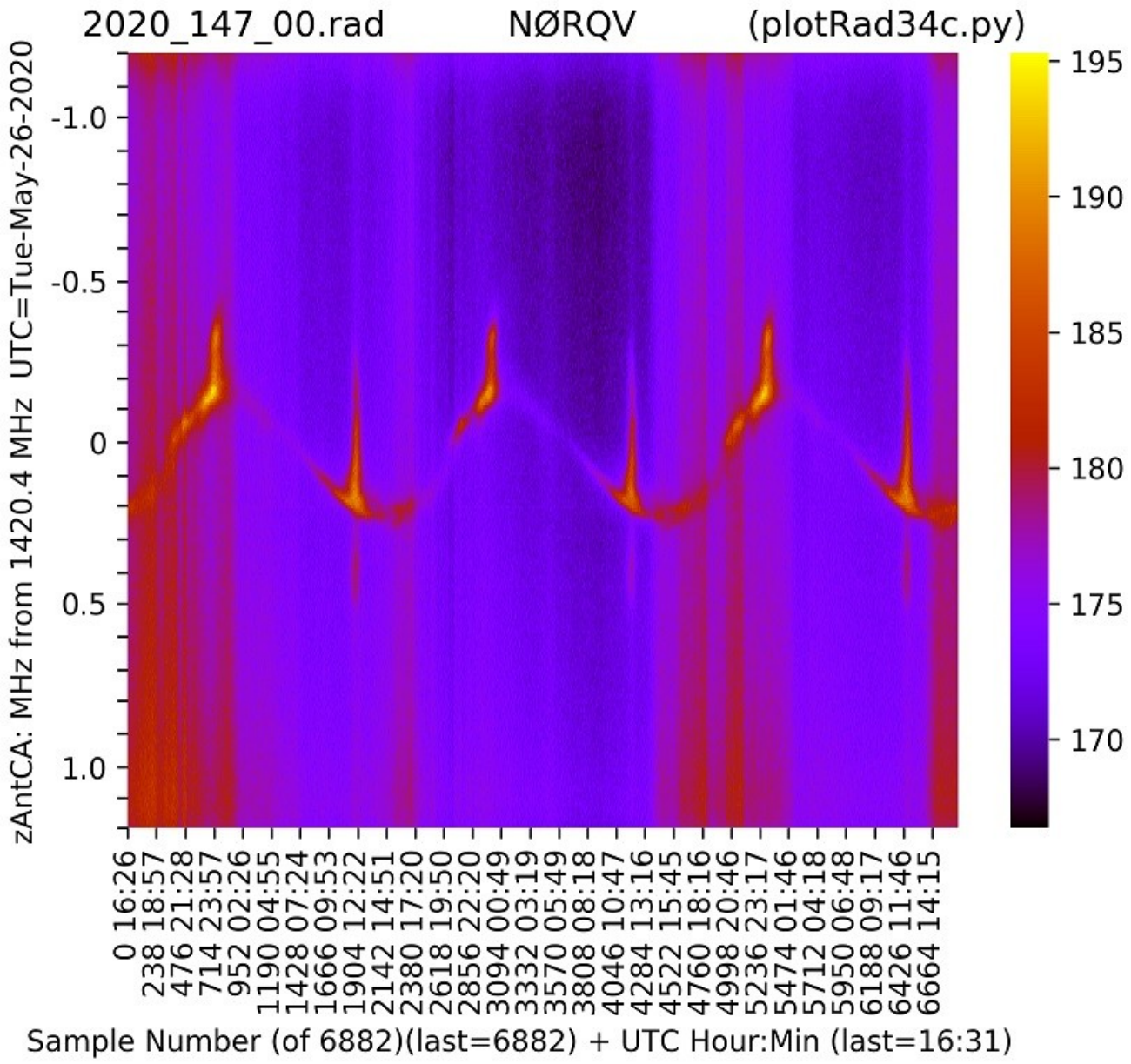
AntCA

AntCA is Ant divided by Cal, for each frequency and time.

The Feed-Calibrator resistor is about 290 Kelvin hot, so I multiply by 290.

AntCA(f, t) = 290 * Ant(f, t) / Cal(f, t)

AntCA is a stepping stone for AntCB later,



Note how that removes much of the frequency (vertical) variability.

AntCB

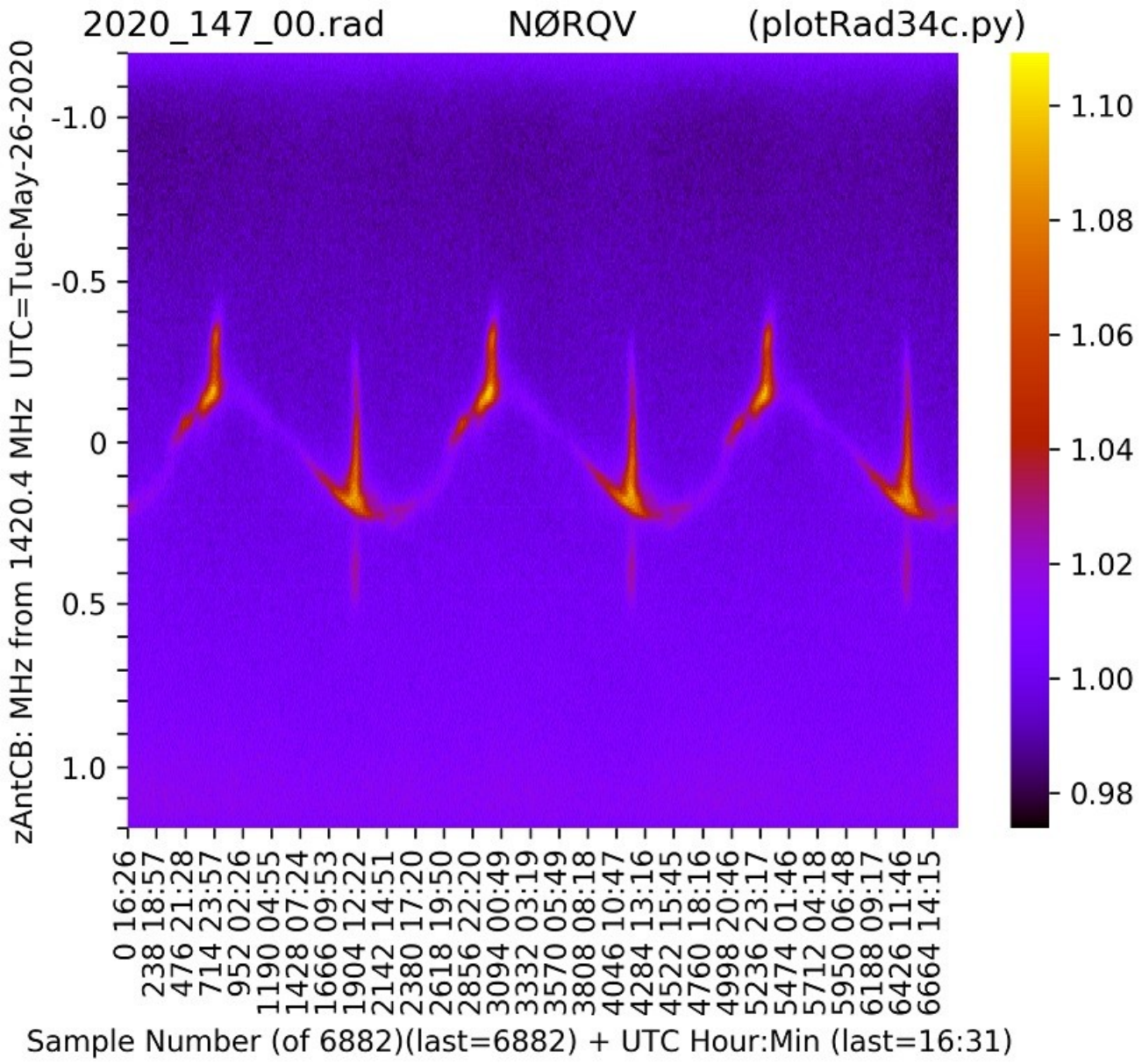
AntCB is combination of the methods above.

AntCB is AntCA minus the average of those dull top 60 AntCA frequency bins and bottom 60 AntCA frequency bins as a baseline in time.

AntCB(f, t) = AntCA(f, t) - AntCABaseline(t)

= 290 * Ant(f, t) / Cal(f, t) - AntCABaseline(t)

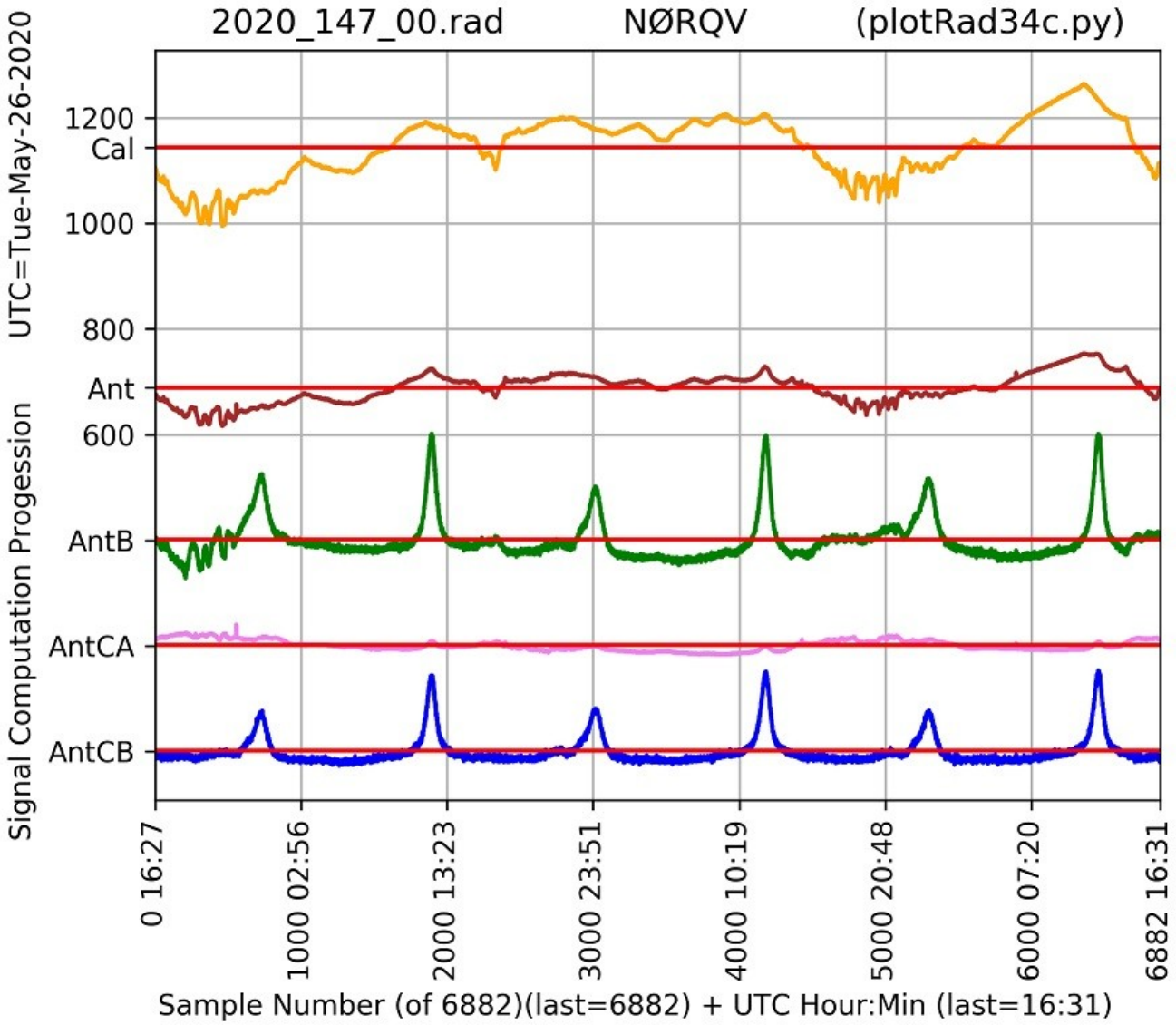
AntCB looks good,



Much better, at least for the interesting 1420 MHz hydrogen signal in the middle frequencies.

But to plot the radio sky, I want signal strength as a function only of time.

Averaging the frequency bins in the plots above, as a function of time yields,



In this 3 day drift scan example,

At the top, the ORANGE Cal input data of the warm feed calibrator averaged about 1144.

Next, the BROWN Ant input data of the cold sky (Azimuth=227.9, Elevation=38.9, Declination= 0.6) averaged about 689.

The bottom BLUE AntCB output line (not the same scale) has more signal, and less gain variation than the brown Ant input. Note the galactic outer and inner arm signal peaks, repeating 3 times.