Intercontinental decametric VLBI

Jupiter DAM observations with KAIRA, LOFAR, LWA, NenuFAR

Olaf Wucknitz + many others

wucknitz@mpifr-bonn.mpg.de

LOFAR Family Meeting
Leiden, 7 June 2024

Max-Planck-Institut
für Radioastronomie

The many others . . .

Krishnakumar Moochickal Ambalappat, Cees Bassa, Leszek Blaszkiewicz, Louis Bondonneau, Tobia Carozzi, Jesus Cazares, Jayce Dowell, Richard Fallows, Julien Girard, Jean-Mathias Griessmeier, Francesco Iraci, Evan Keane, Joern Kuensemoeller, Laurent Lamy, Alan Loh, Corentin Louis, Joe McCauley, Derek McKay, Mariusz Pozoga, Tomasz Sidorowicz, Bartosz Smierciak, Marian Soida, Janis Steinbergs, Sai Chaitanya Susarla, Greg Taylor, Philippe Zarka

Intercontinental decametric VLBI

- First attempt 2013
- Current project: Jupiter and pulsars
- Jupiter decametric emission (DAM)
- Cycle 0 interferometry project
- Correlating 2024 data
- Are there fringes?
- Interplanetary scintillation
- Outlook

First experiment: B0809+74 one hour on 26 Mar 2013 LBA

[http://kaira.sgo.fi/2013/03/vlbi-with-kaira-lofar-and-lwa.html]

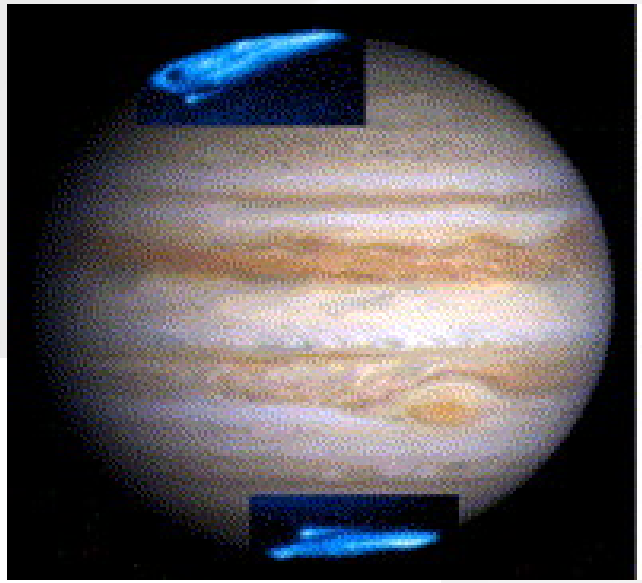
Current project

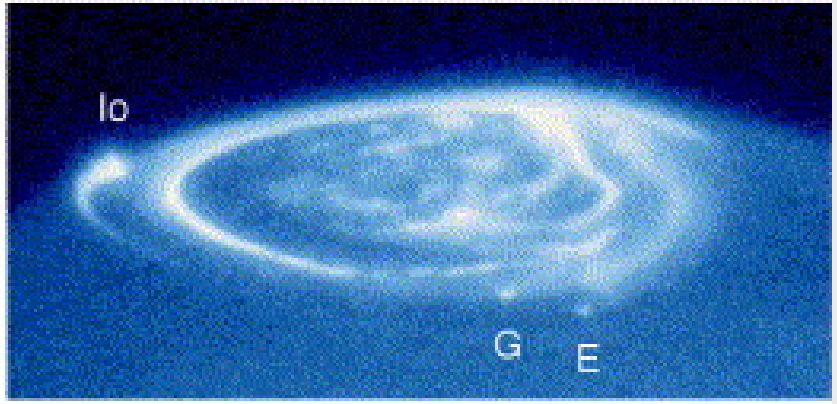
- no fringes in 2013: try again with different targets
  - ⋆ pulsars: select bright and not too scattered
    full low band available
  - ⋆ Jupiter: very strong, only $\leq 40\,\mathrm{MHz}$ (cyclotron)
    try with signals from both hemispheres

- stations
  - ⋆ KAIRA
  - ⋆ LOFAR IS (local time), LOFAR RS+2.0 (DDT20_007)
  - ⋆ LWA1,-SV,-NA,-OVRO (DW005)
  - ⋆ NenuFAR (LT03,LT07)

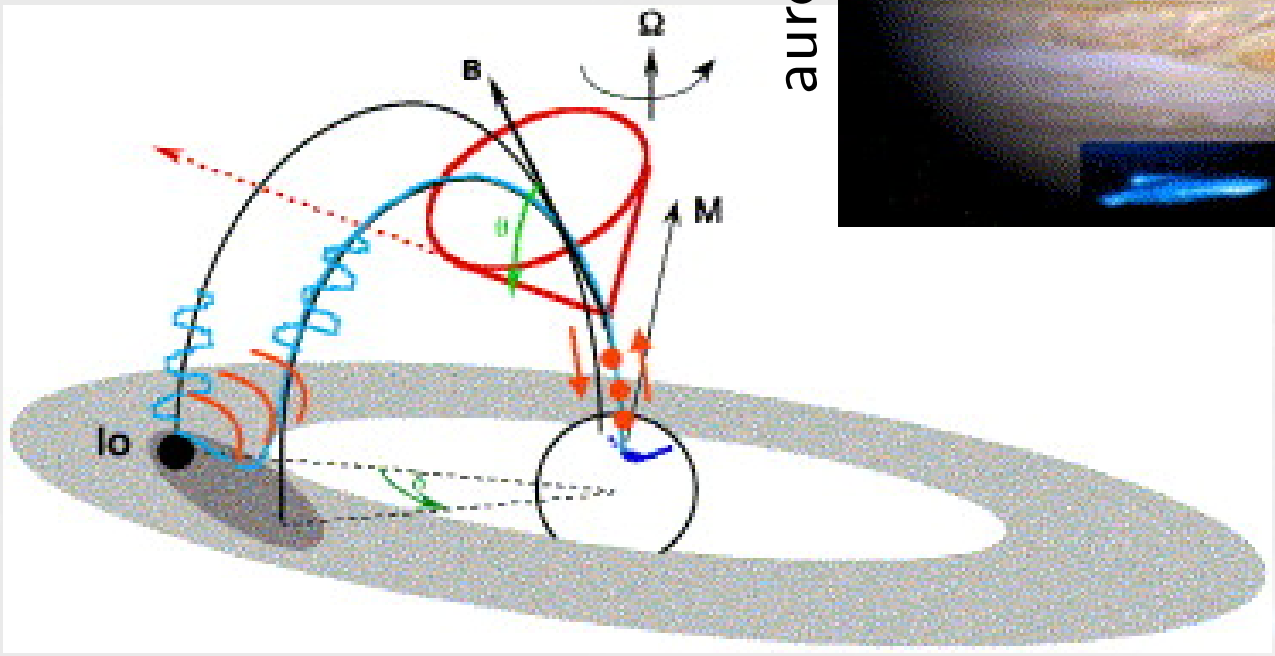
Jupiter: sources of decametric emission (DAM)

aurora





Io



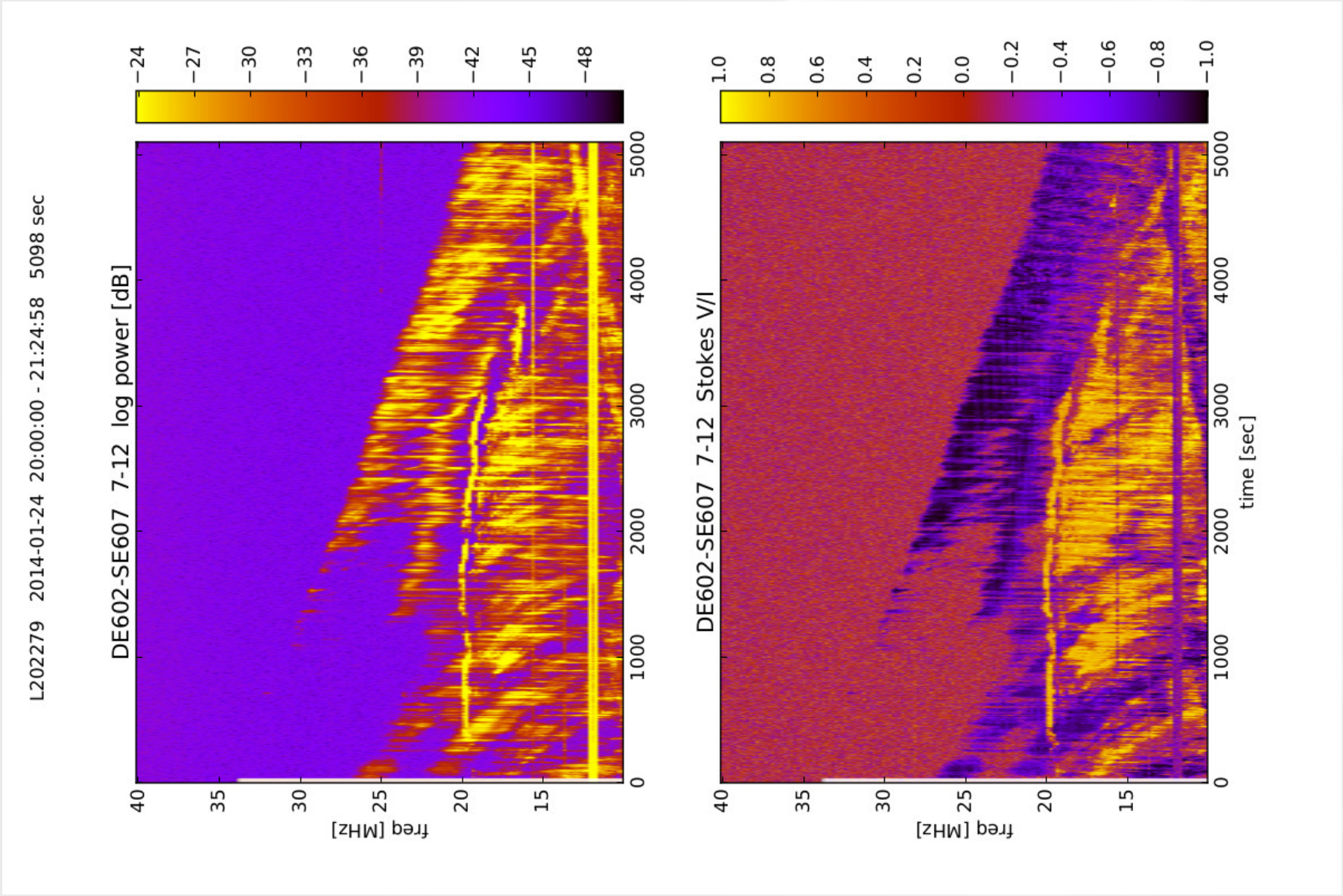
[Zarka (2004)]

Jupiter DAM: project LC0_002

- with Philippe Zarka
- data taken 2013–2014, not all analysed
- aim: measure motion or offsets between regions
- LBA via ILT recording: some core, some international
- integer sample delay compensation via ILT correlator
- own correlation: FT/PPF with fine delay compensation
- large data volumes (175 TB kept)

[https://fpra.mpifr-bonn.mpg.de/doku.php?id=projects:jupiter:first]

L202279 2014-01-24 Stokes I and V

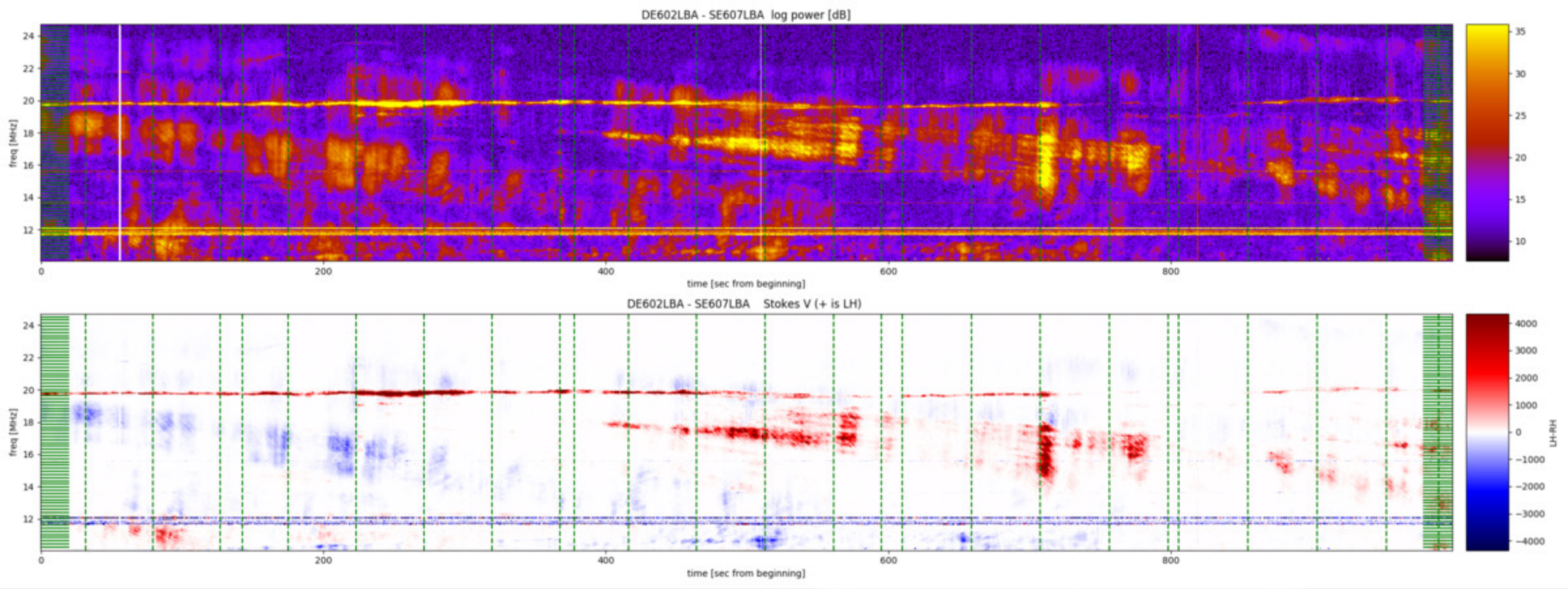


Calibration procedure

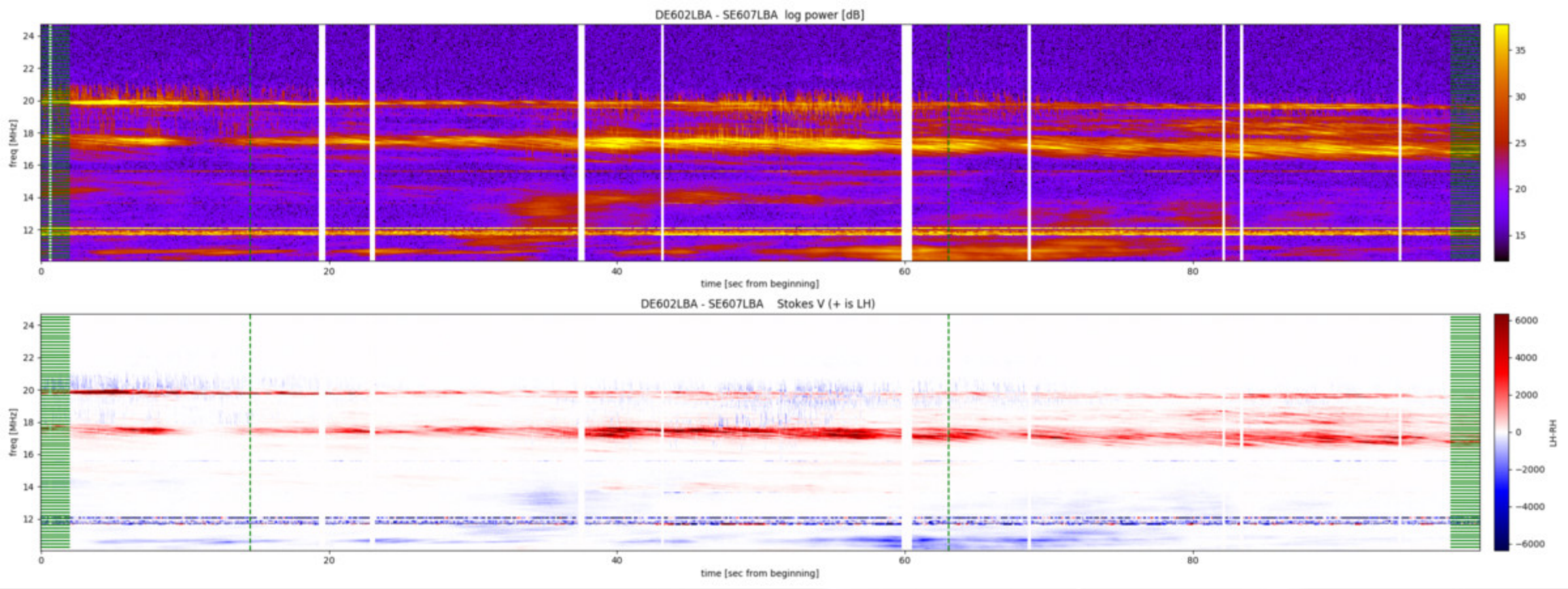
- circular polarisation basis
- eigenvector approach (coherent, 100 % polarised!)
- emission from both hemispheres

	dependencies				
	pol	hemisphere	station	time	freq (for phase)
FR near Jupiter	R-L	N/S		slow	ν^{-2}
FR ionospheric	R-L		yes	fast	ν^{-2}
ionospheric delay			yes	fast	ν^{-1}
clock			yes	slow	ν^{1}
phase offset			yes	slow	ν^{0}
absolute position			yes	?	(ν^{1})
relative position		N-S	yes	?	(ν^{1})

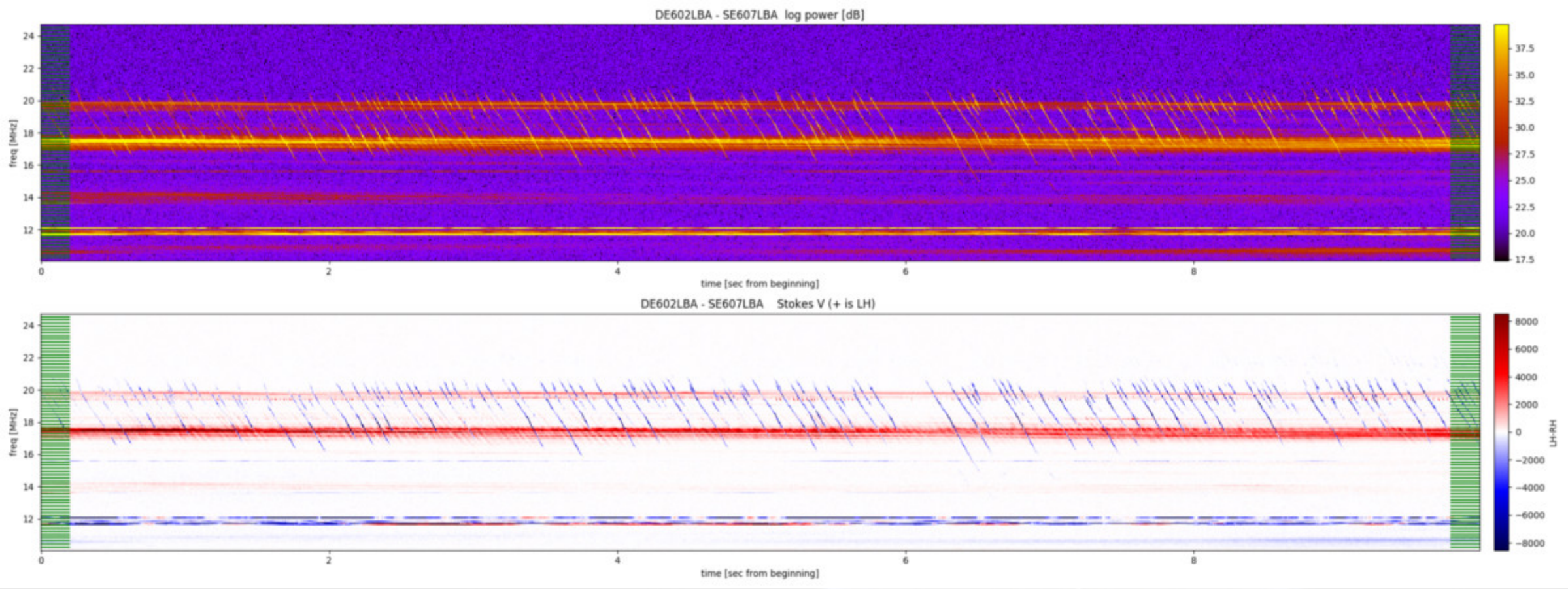
L202279 2014-01-24 1000 sec around 20:16:10.5



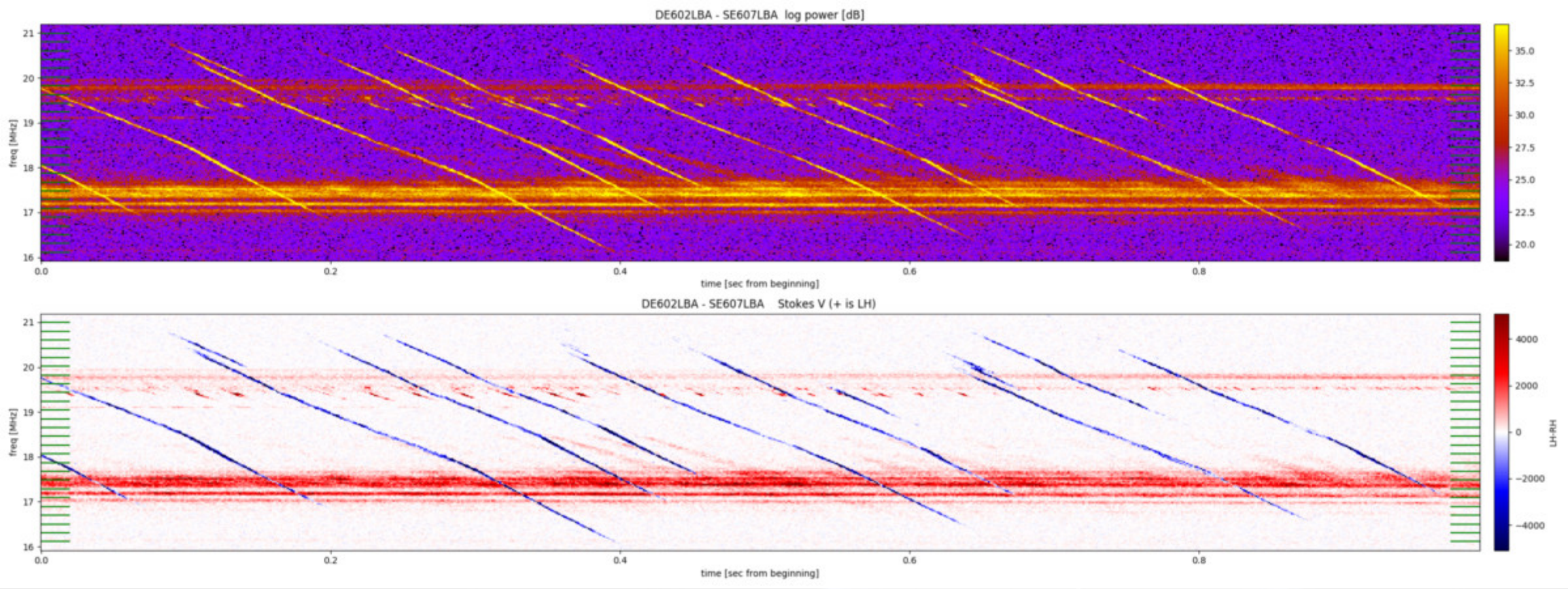
100 sec


DE602LBA - SE607LBA log power [dB]
freq [MHz]
time [sec from beginning]
DE602LBA - SE607LBA Stokes V (+ is LH)
freq [MHz]
time [sec from beginning]
LH-RH

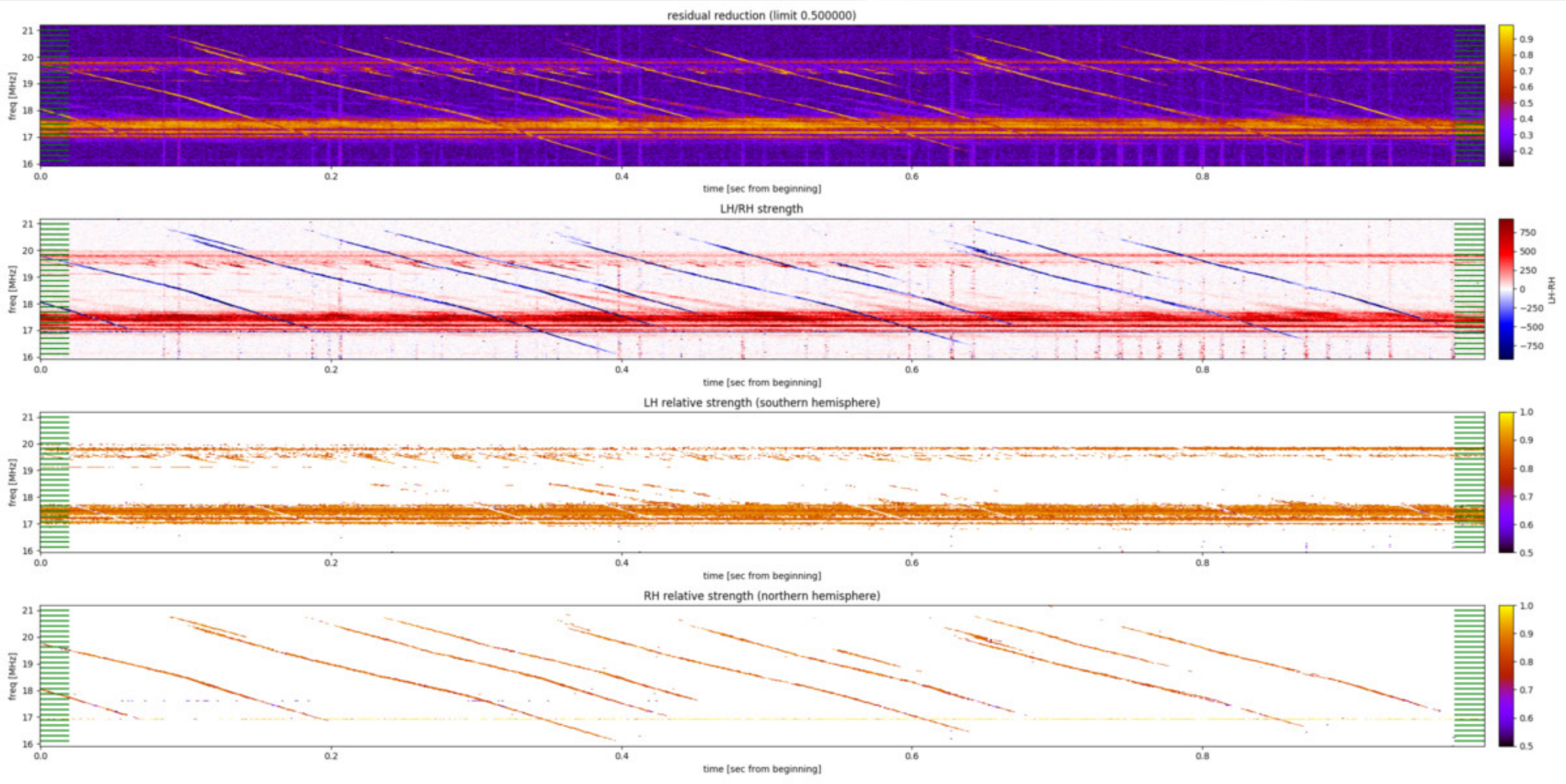
10 sec


DE602LBA - SE607LBA log power [dB]
freq [MHz]
time [sec from beginning]
DE602LBA - SE607LBA Stokes V (+ is LH)
freq [MHz]
time [sec from beginning]
LH-RH

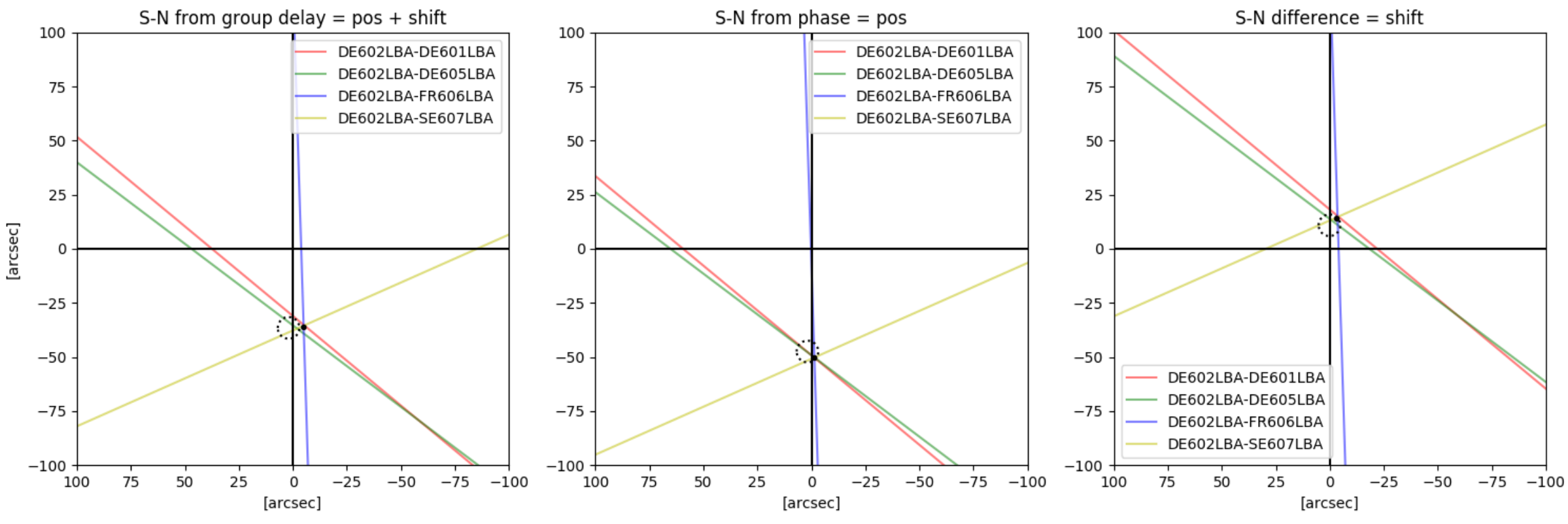
1 sec


DE602LBA - SE607LBA log power [dB]
freq [MHz]
time [sec from beginning]
DE602LBA - SE607LBA Stokes V (+ is LH)
freq [MHz]
time [sec from beginning]
LH-RH

Eigenvector decomposition

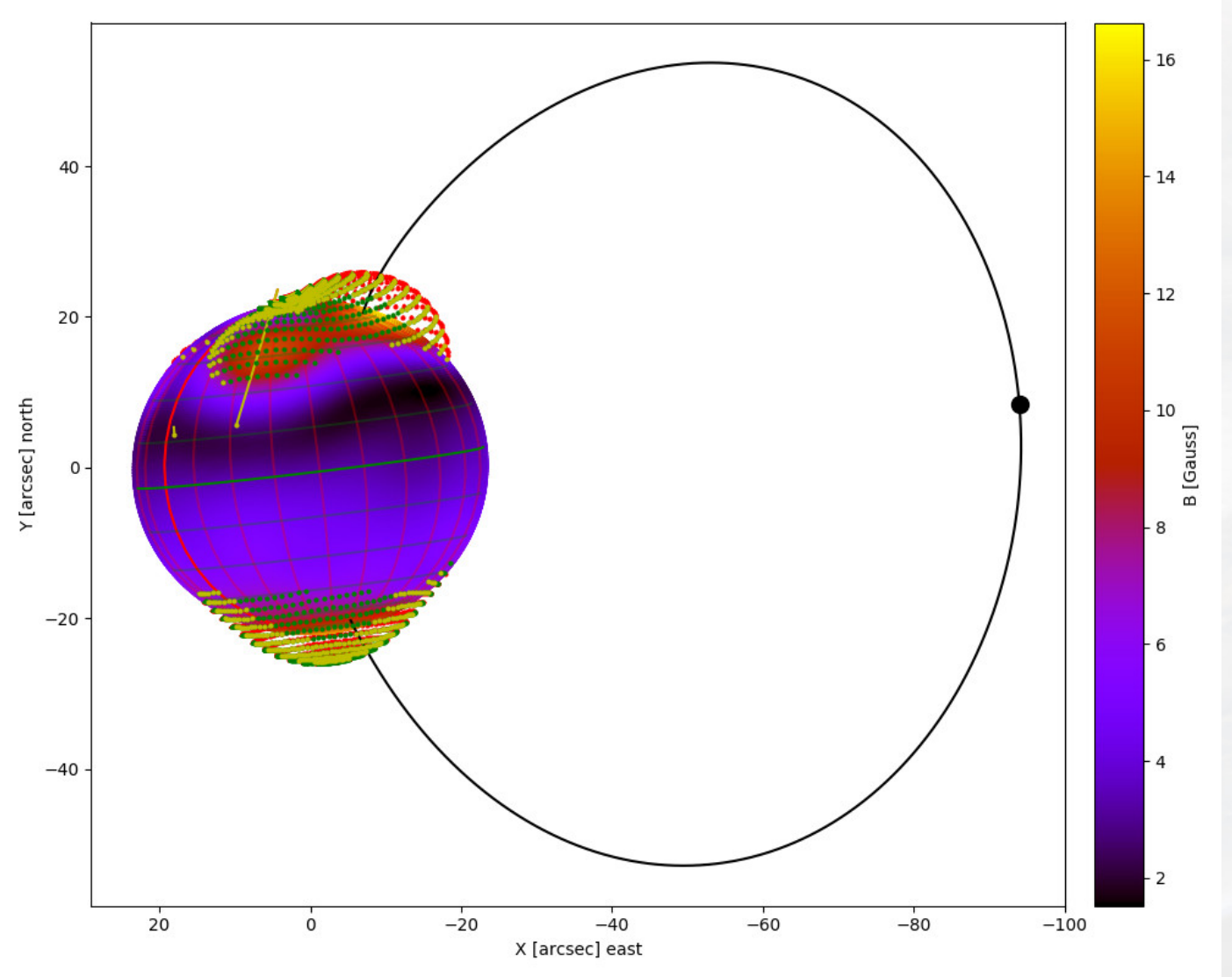


Relative positions and shifts with frequency (global)

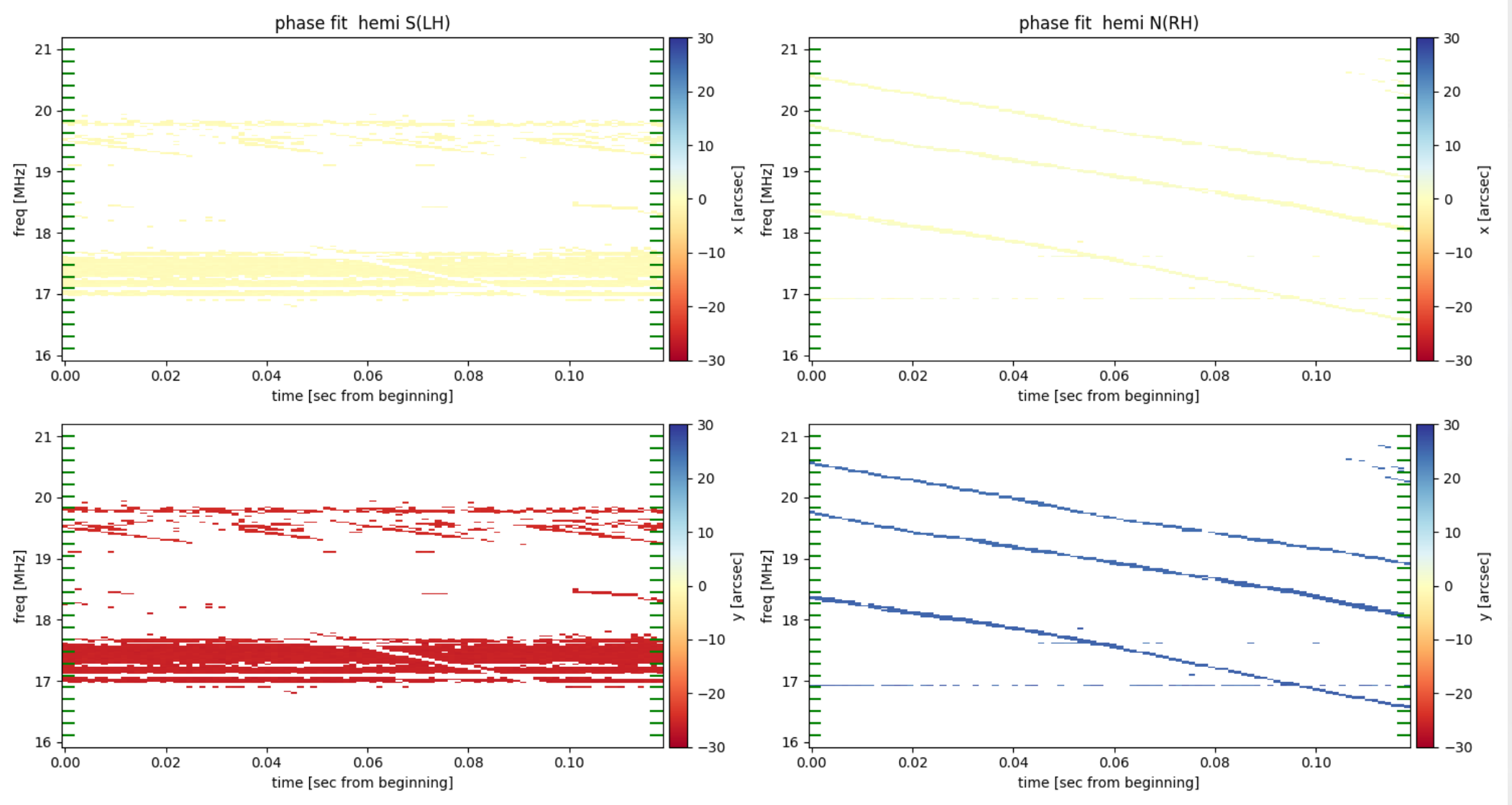


lines/points: fit, circles: expectation

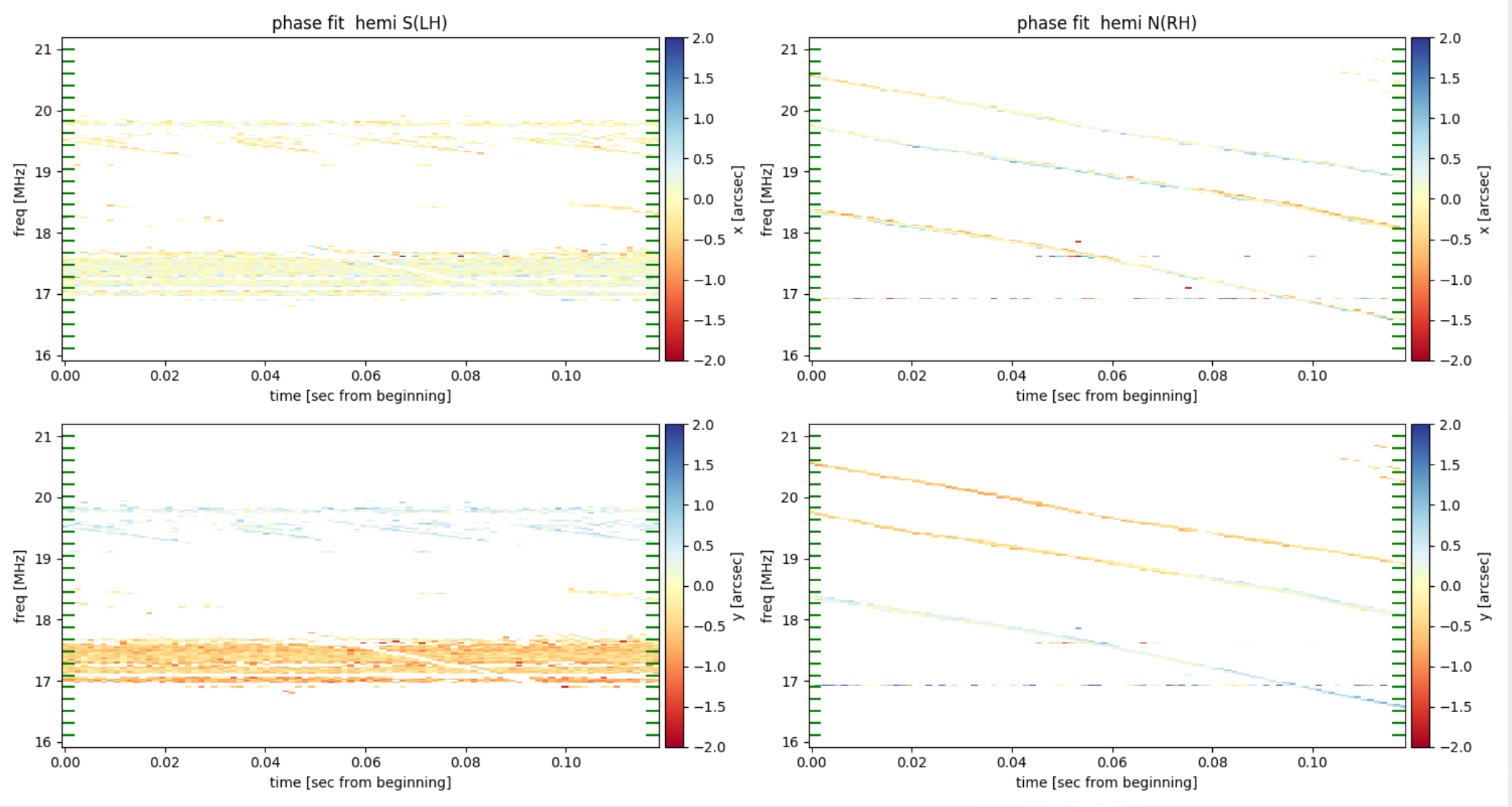
Relative positions and shifts: expectations



Positions in detail: position (relative to mean)



Positions in detail: drift with frequency

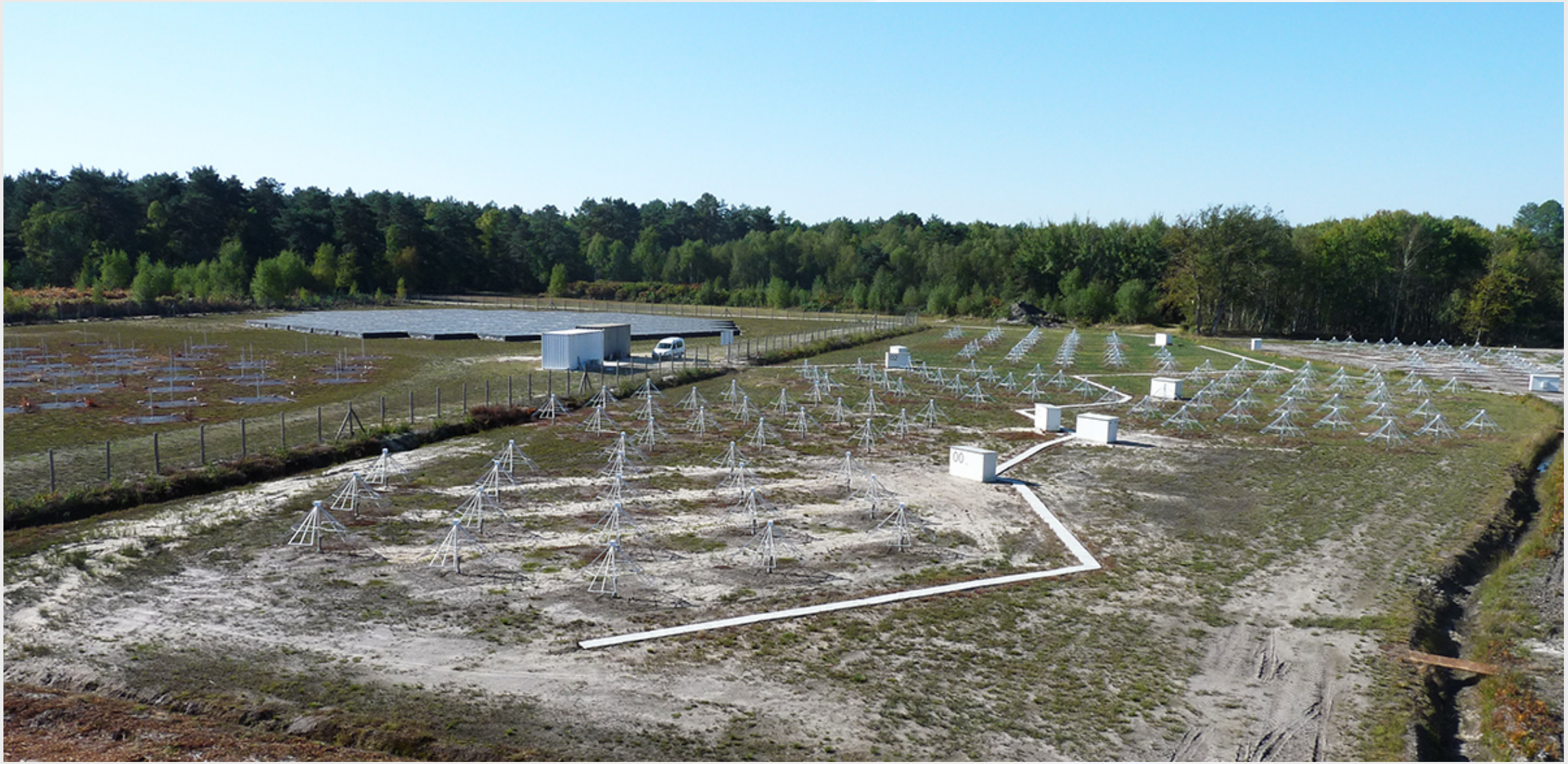


New observations

UTC	target	stations
2023-12-27 20:30–22:30	Jupiter	LWA1,-SV, KAIRA, NenuFAR, DE601–609, PL610,612, IE613, LV614
2024-01-16 23:00–24:00	B0329+54	LWA1,-SV, NenuFAR, DE602–609, SE607, PL610,612, LV614
2024-01-17 04:30–05:15	B0809+74	LWA1,-SV, NenuFAR, DE602–609, PL610,612, LV614
2024-01-17 05:15–06:00	B0950+08	LWA1,-SV, NenuFAR, DE602–609, PL610,612, LV614
2024-03-04 18:30–20:30	Jupiter	LWA1,-SV,-NA,-OVRO, KAIRA, NenuFAR, DE602–609, SE607, PL610–612, IE613, LV614, RS+2.0
2024-04-06 17:30–19:30	**Jupiter**	**LWA1,-SV,-NA,(-OVRO), KAIRA, NenuFAR, DE602–609, FR606, SE607, PL610,612, IE613, LV614, RS**

55 TB + RS+2.0

Stations: LOFAR+NenuFAR



[https://www.obs-nancay.fr/wp-content/uploads/2019/05/nenufar_reseaux.jpg]

Stations: LWA

[https://64.media.tumblr.com/tumblr_lfwnhuldYu1qz4s5wo1_1280.jpg]

Stations: KAIRA

[https://www.sgo.fi/KAIRA/press/KAIRA_20131103_kairascape.jpg]

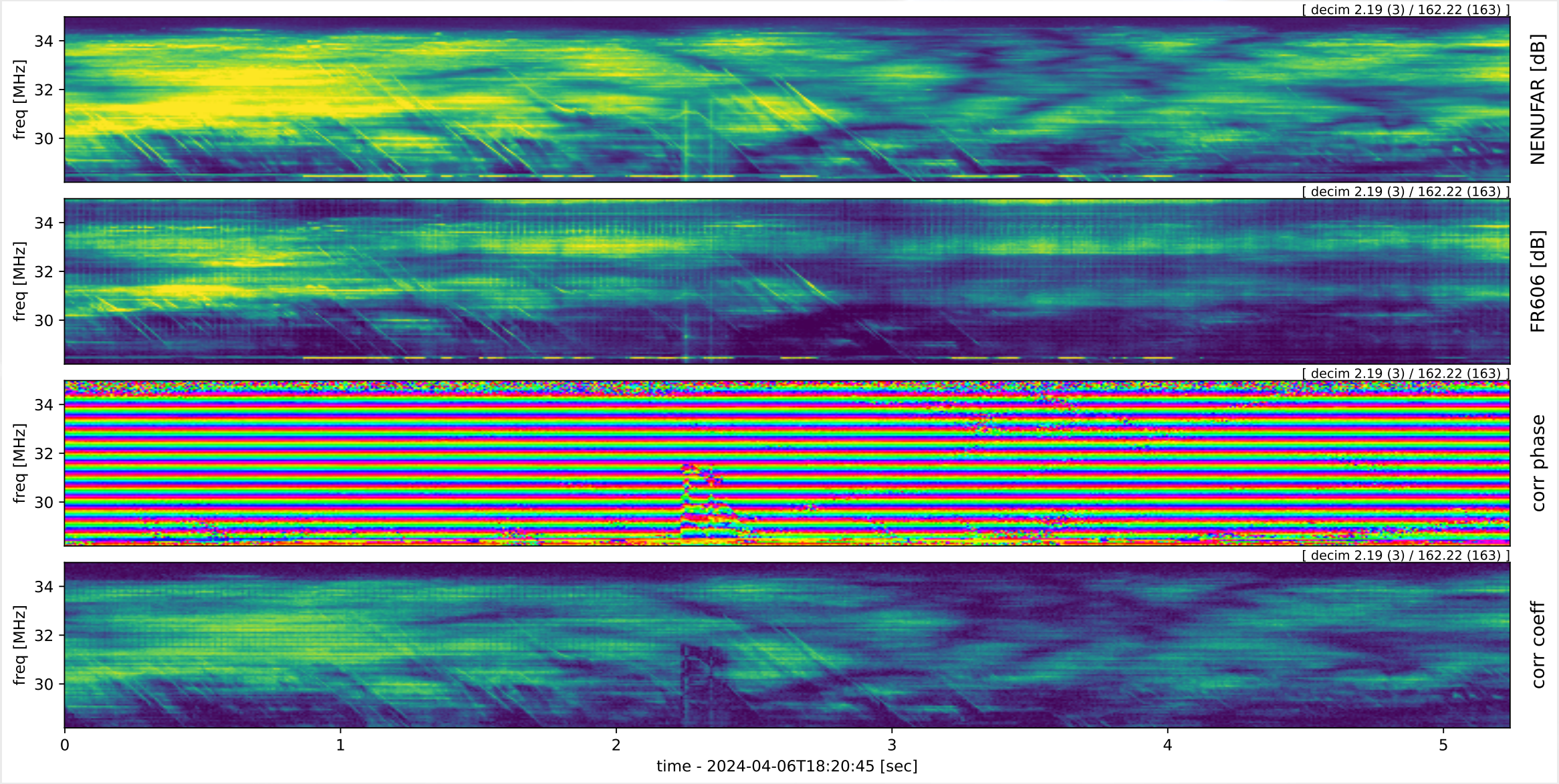
- space physics, solar physics, ionosphere *and astronomy*
- participation in LOFAR offline VLBI, pulsar scintillation
- logistics difficult

many thanks to Derek McKay!

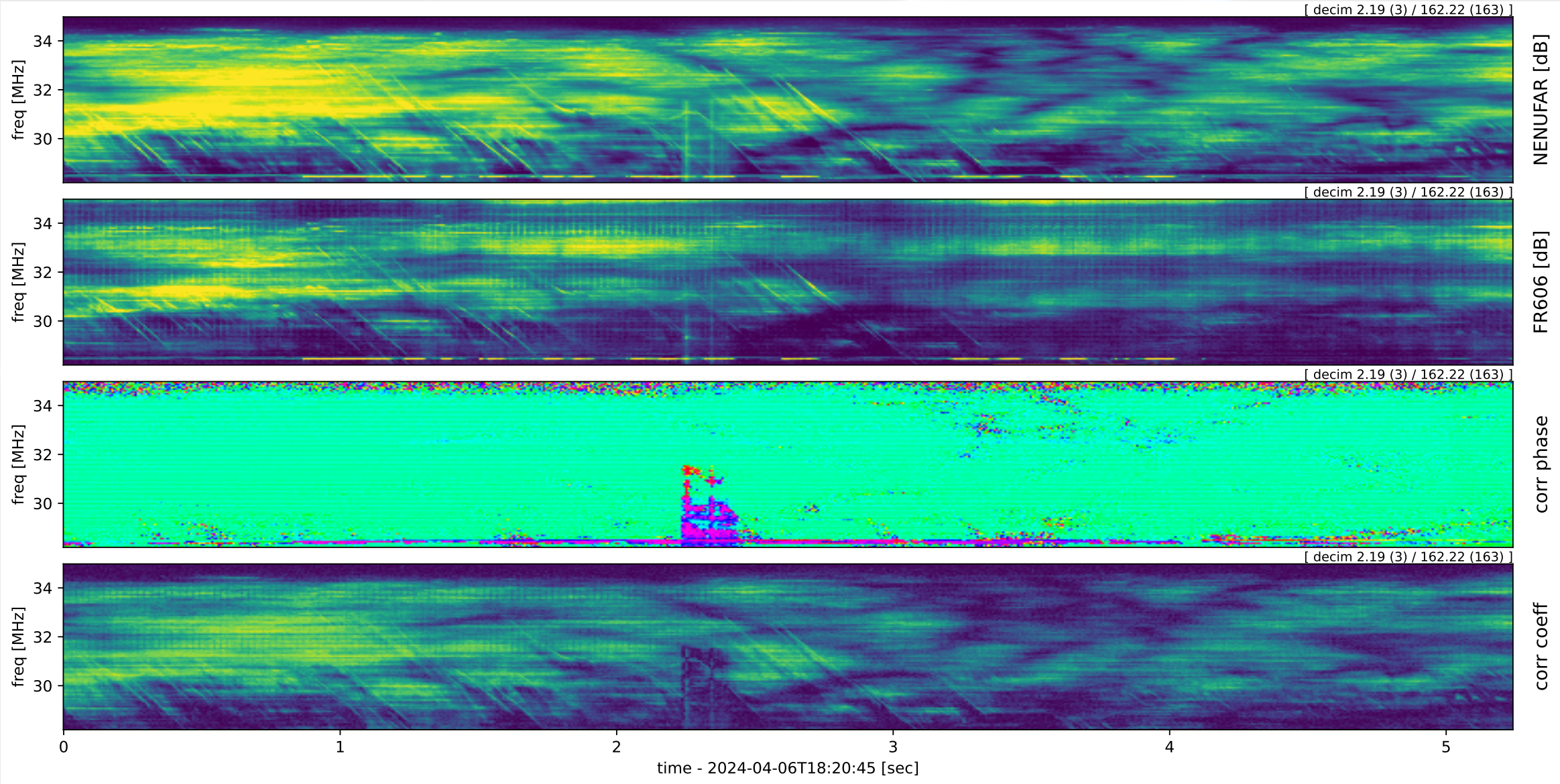
First look: 2024-04-06 17:30–19:30

- selected ca. 4 sec starting at 18:20:45 UTC
- form approximate circular R/L
- delay compensation, channelisation
  - ⋆ delay model: `difxcalc` interface to `CALC11`
  - ⋆ integer sample shift
  - ⋆ channelise to $1.5625\,\mathrm{kHz}/n$ $n = 1$ or 4
    - ∗ LOFAR+KAIRA+NenuFAR: $125 \cdot n$
    - ∗ LWA: $12544 \cdot n$ (plus shift)
  - ⋆ fractional shift and fringe stopping
- "correlate" with/-out averaging
- fit and correct for delay and phase curvature

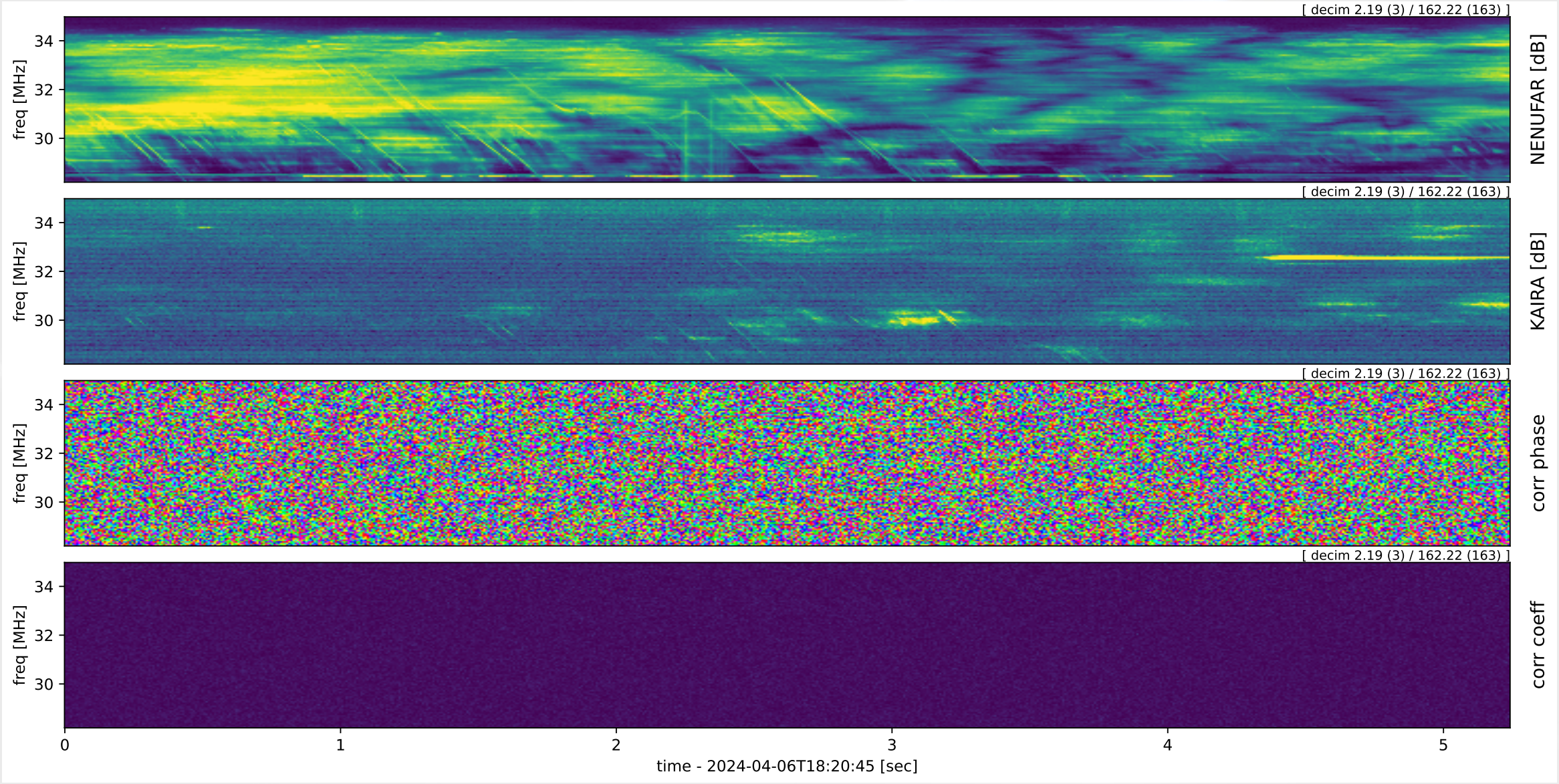
NenuFAR – FR606



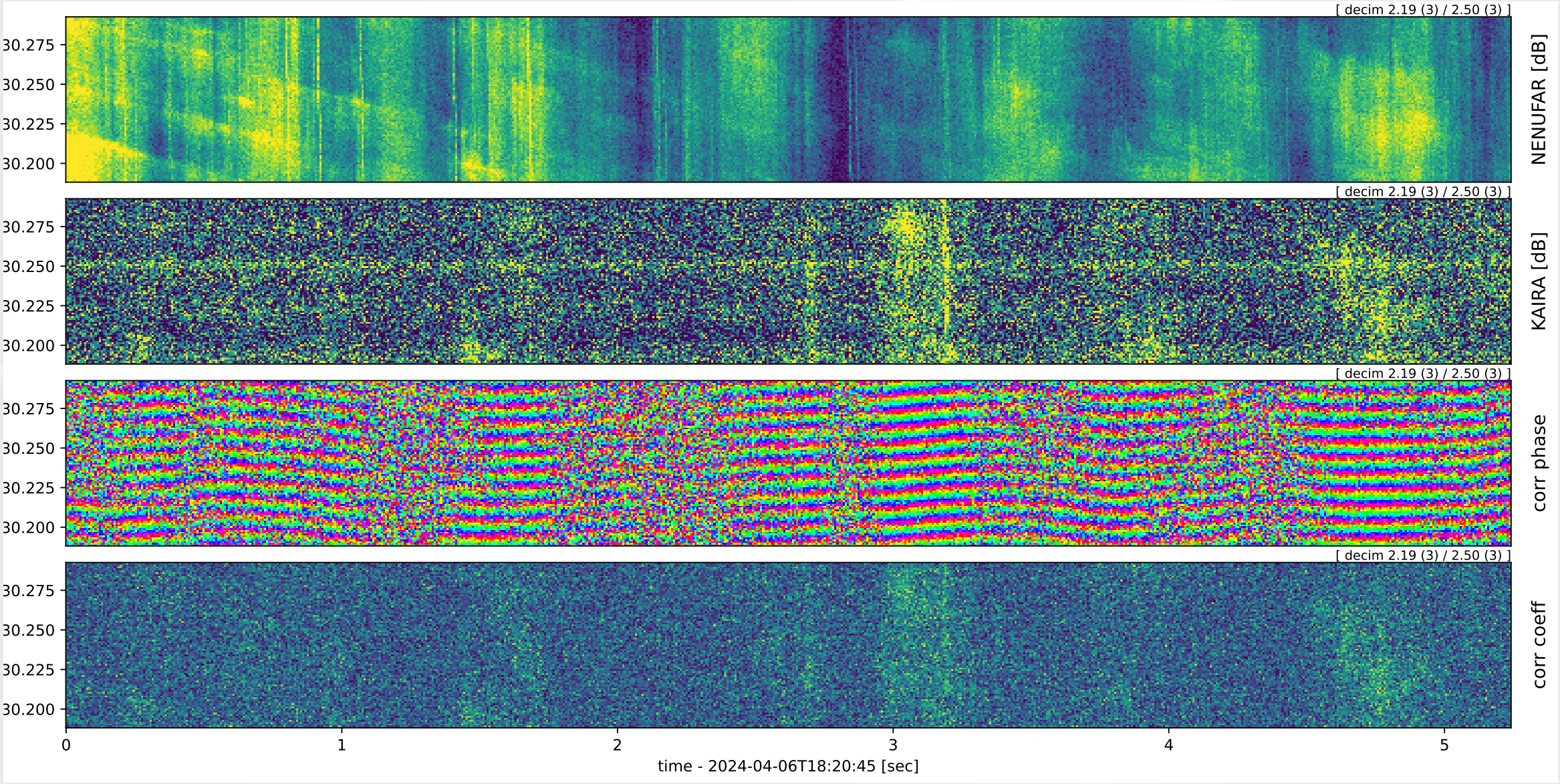
NenuFAR – FR606 corrected



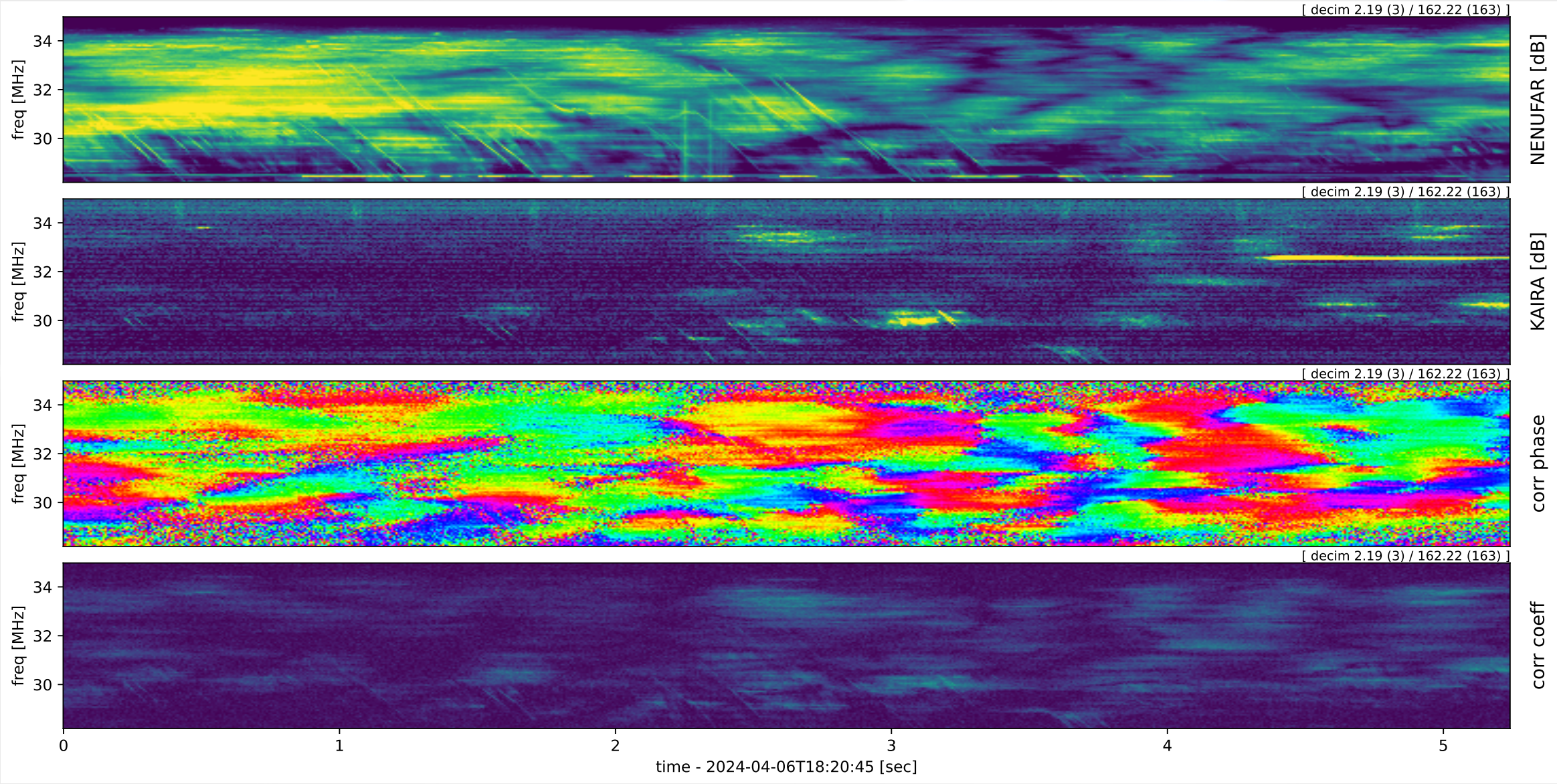
NenuFAR – KAIRA



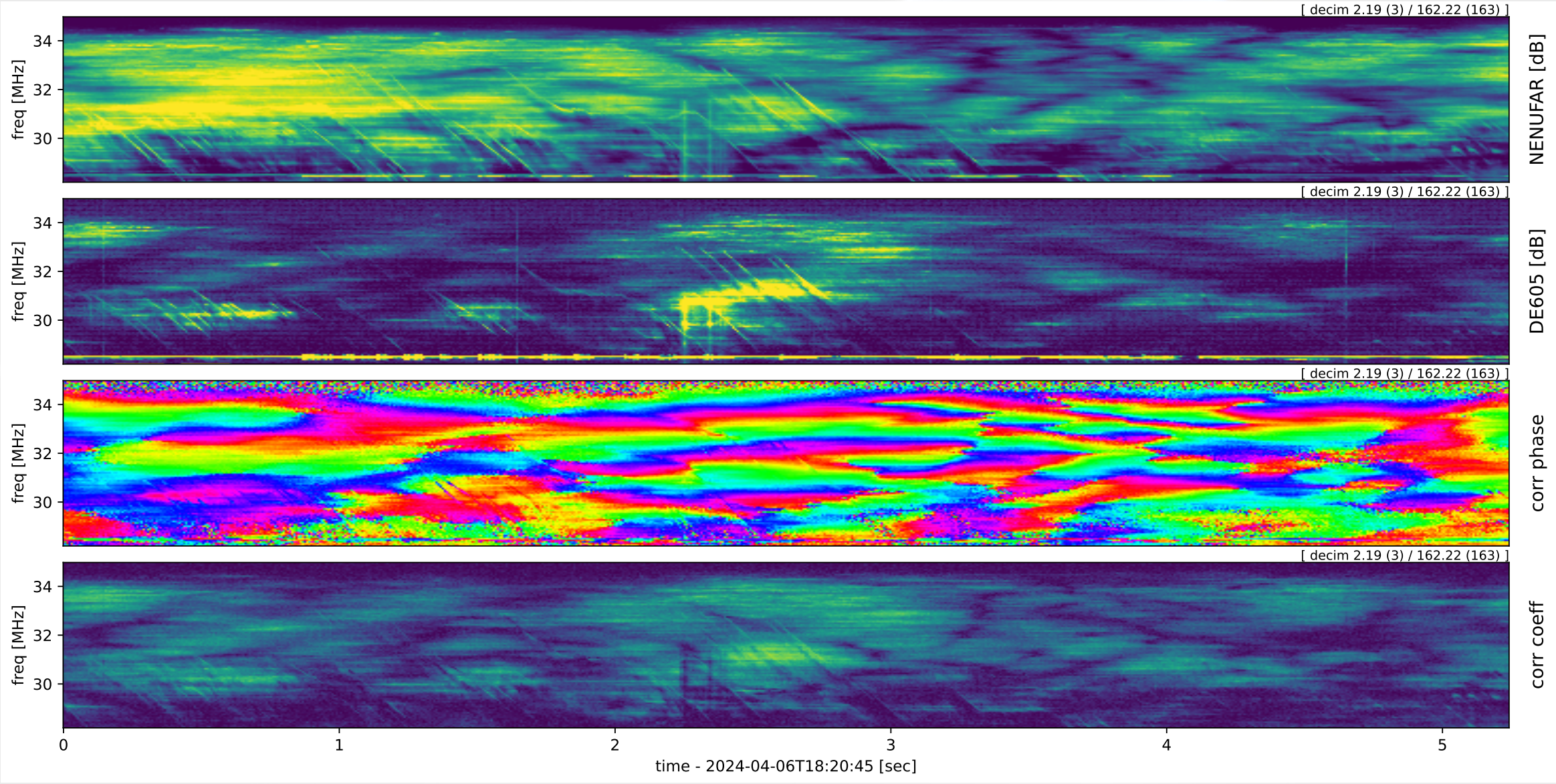
NenuFAR – KAIRA zoom-in



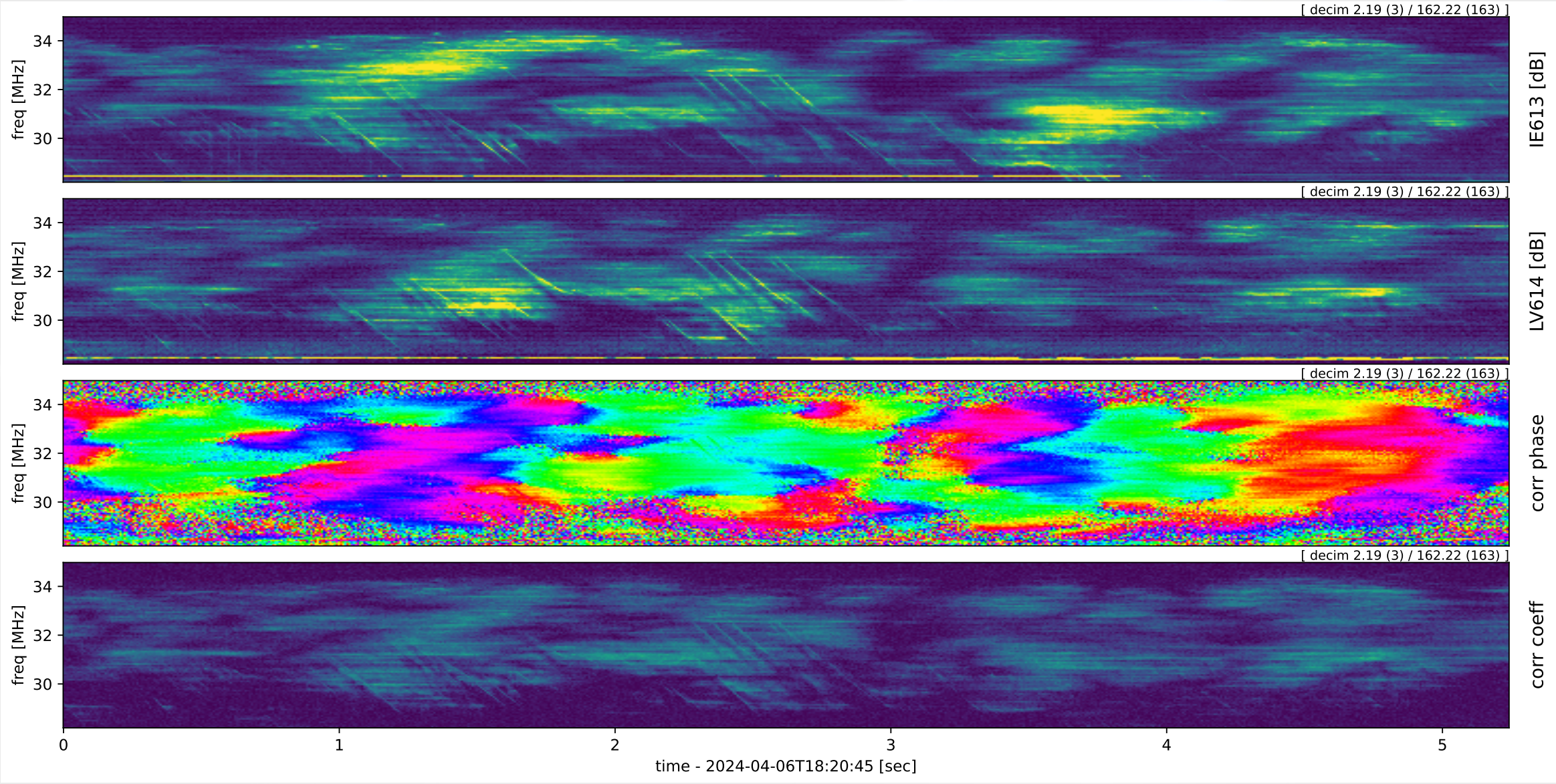
NenuFAR – KAIRA corrected



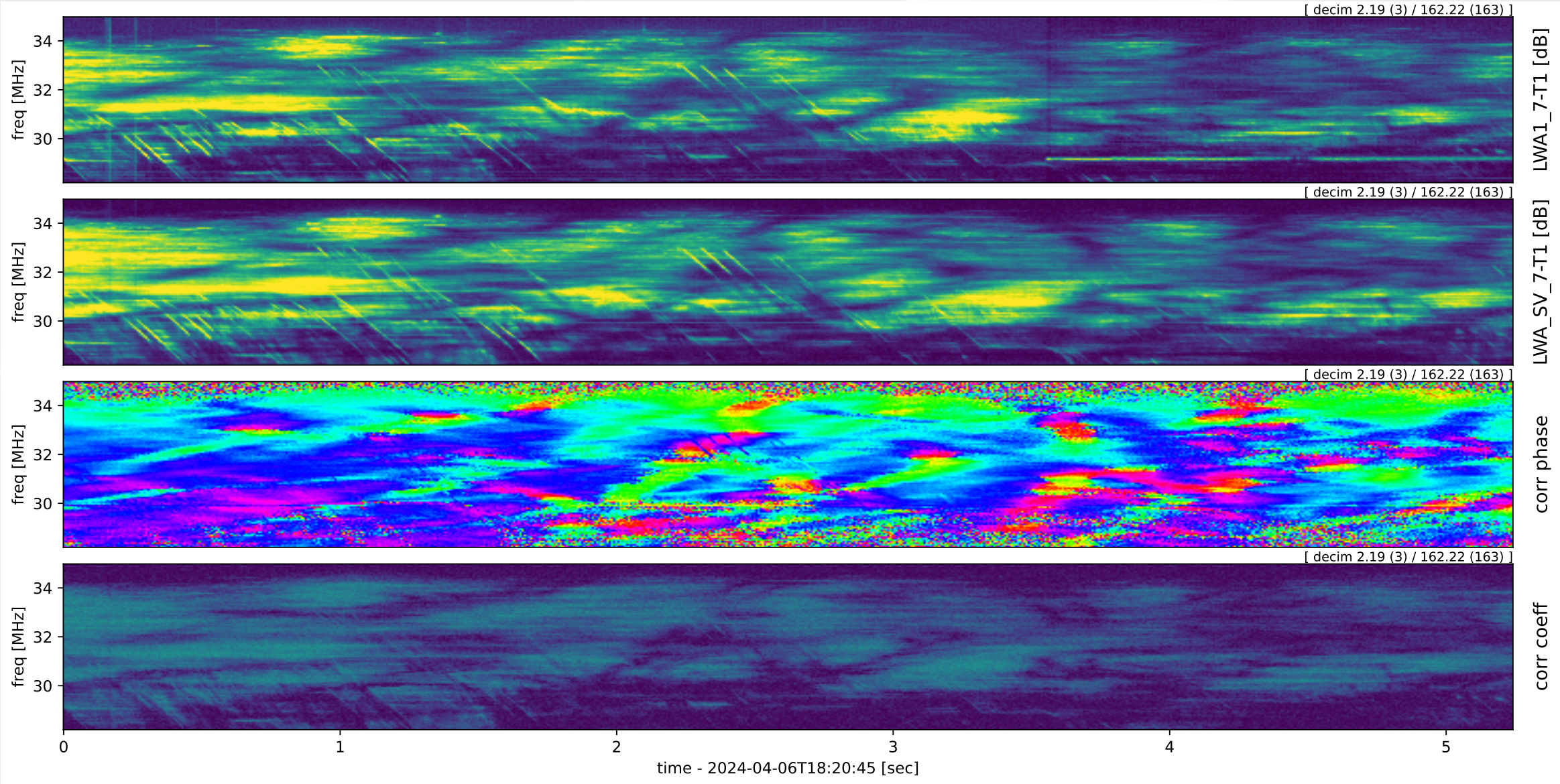
NenuFAR – DE605 corrected



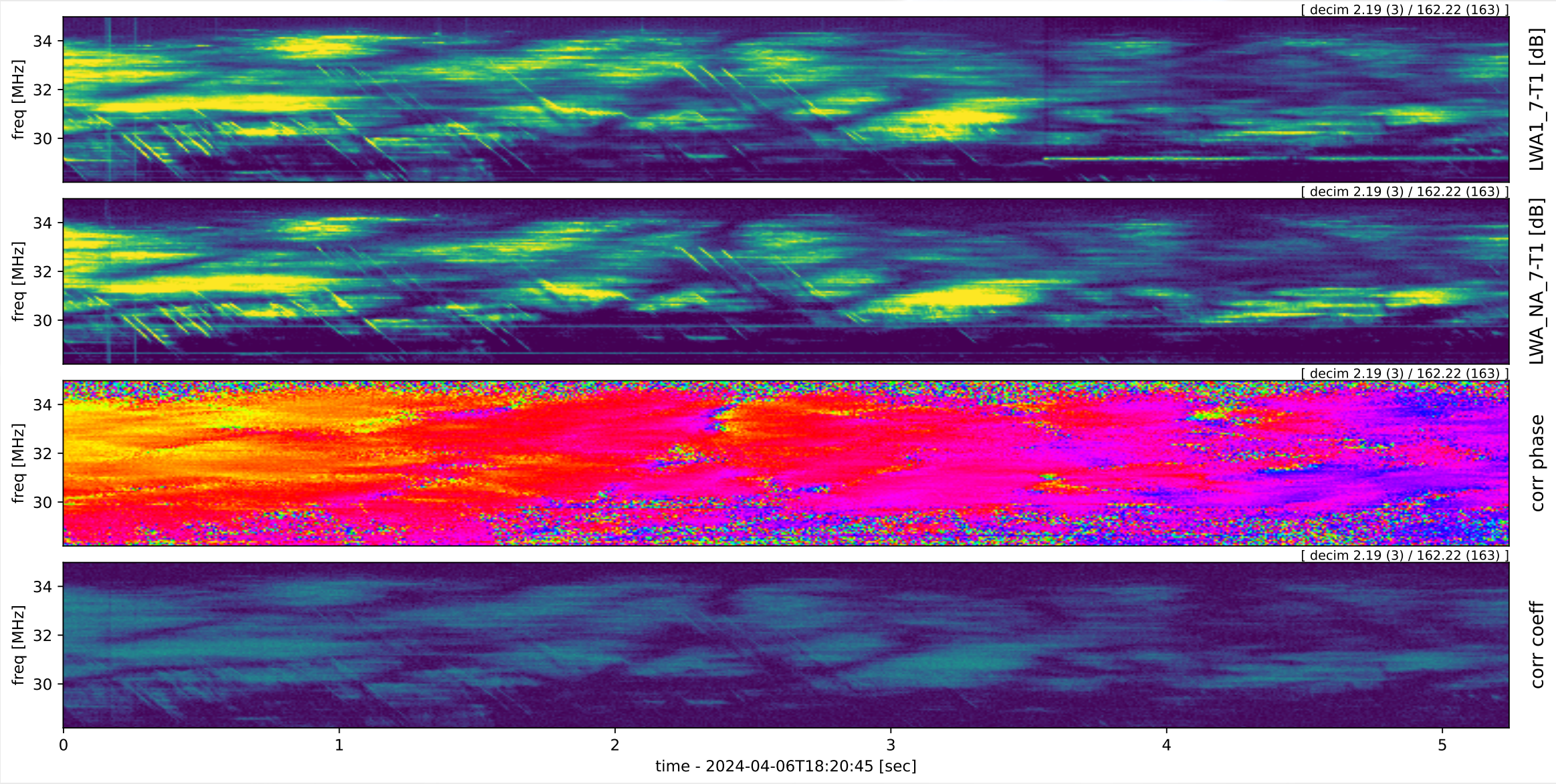
IE613 – LV614 corrected



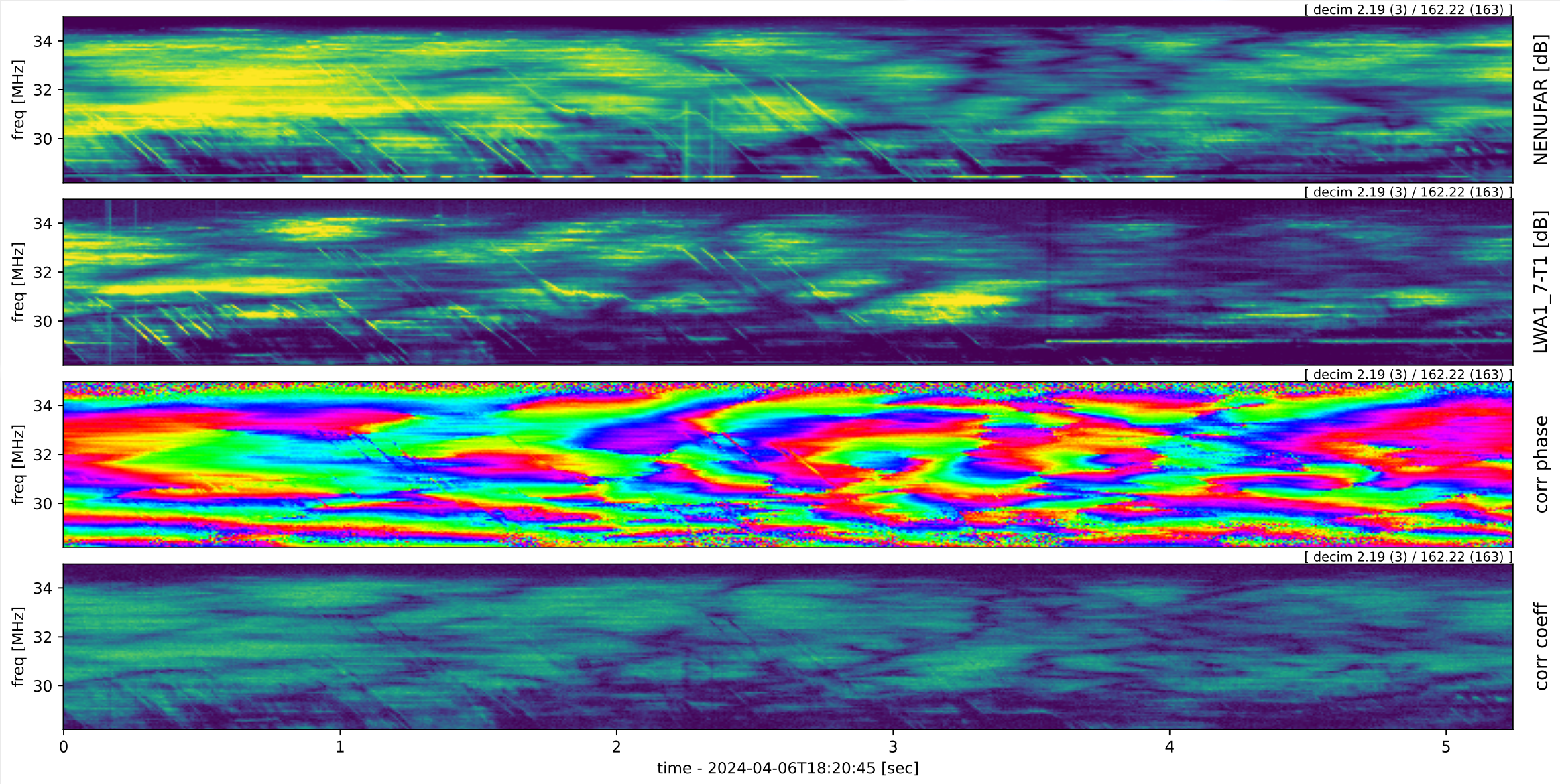
LWA1 – LWA-SV corrected



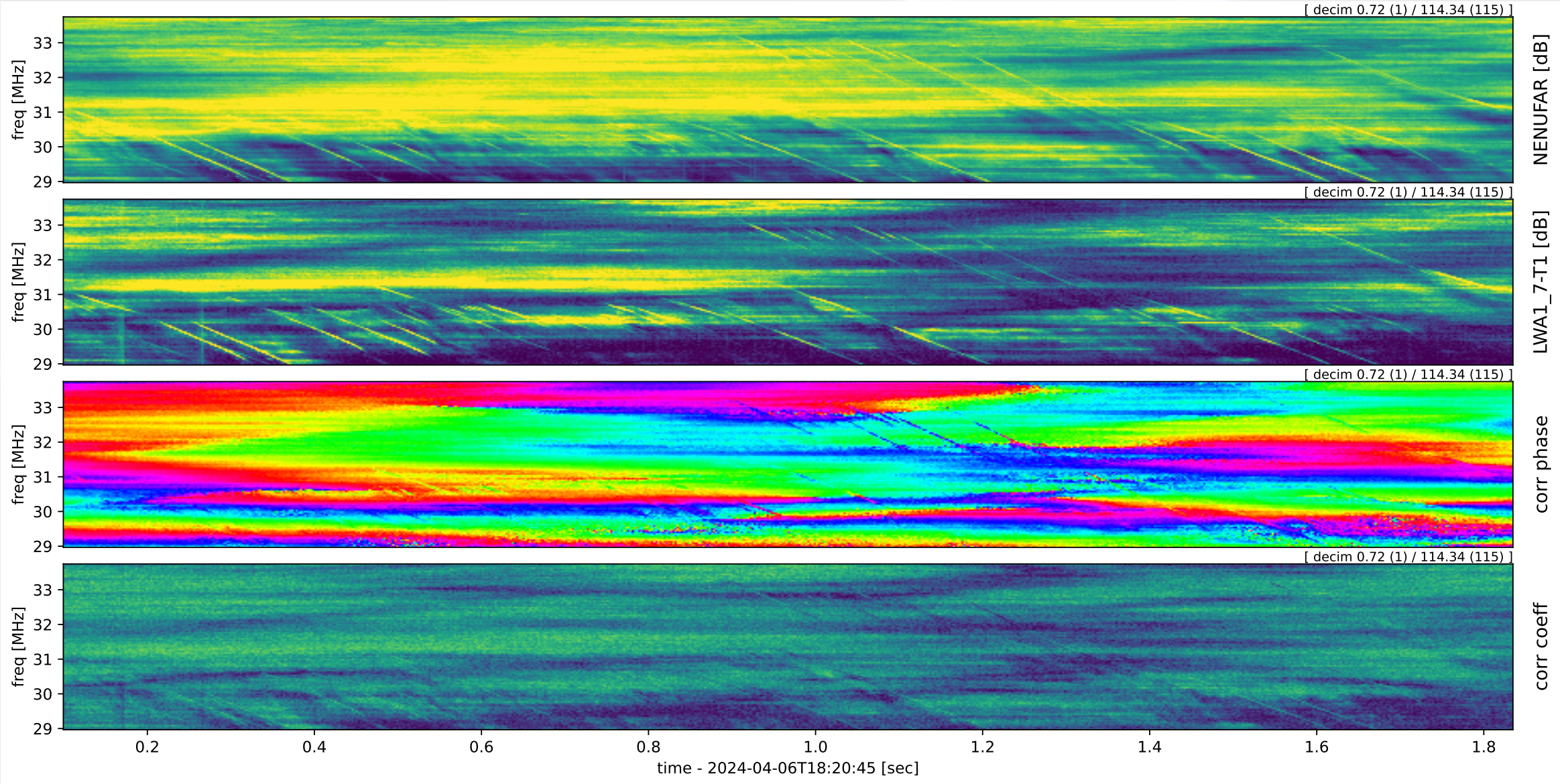
LWA1 – LWA-NA corrected



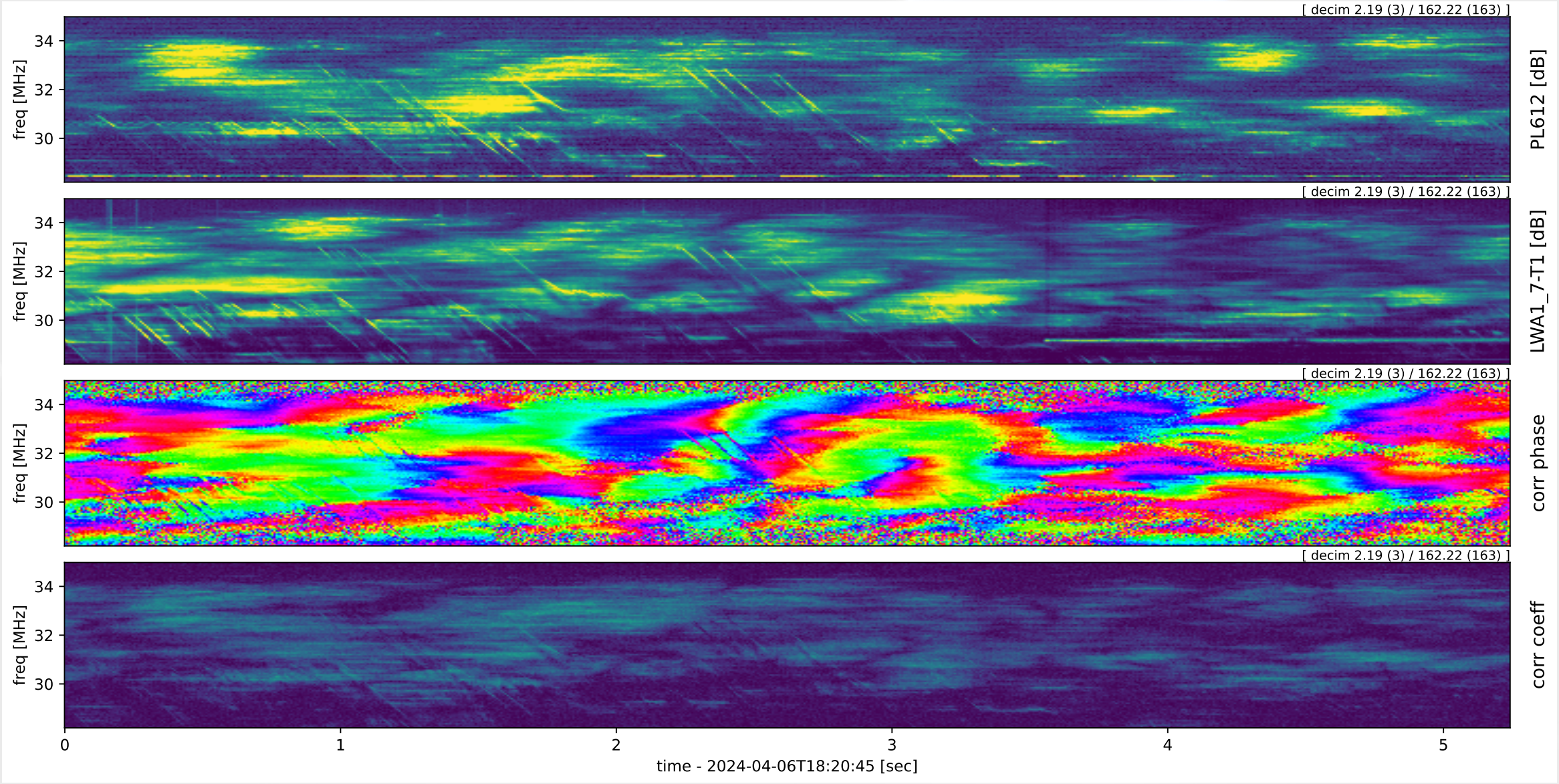
NenuFAR – LWA1 corrected



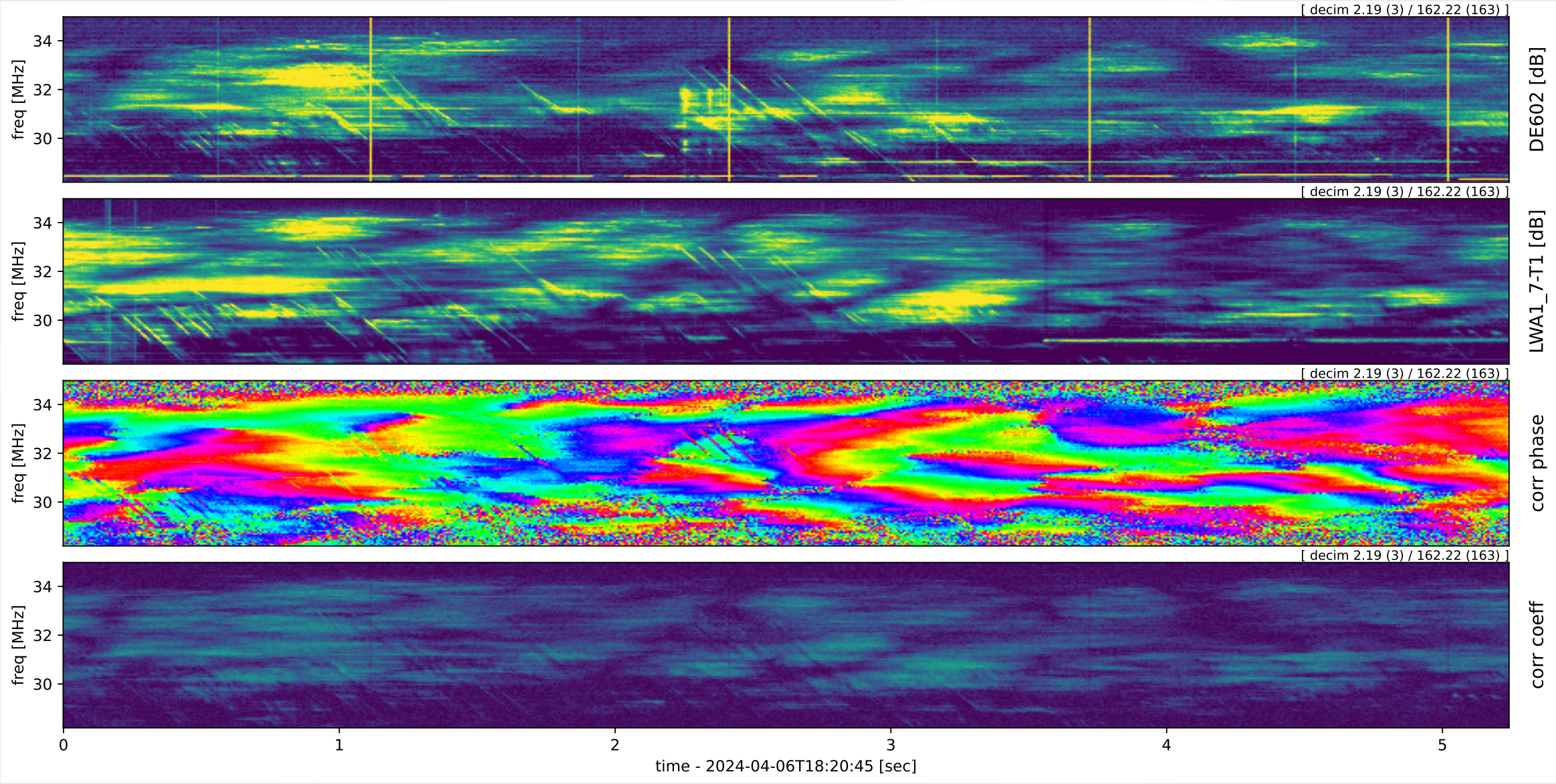
NenuFAR – LWA1 corrected zoom-in



PL612 – LWA1 corrected, absolute baseline 8346 km



DE602 – LWA1 corrected, projected baseline 7970 km



How to continue

- understand instrumental effects
- eigenvector decomposition in chunks
- separate and study IPS
- use frequency dependence to calibrate station response
- disentangle source components (e.g. streaks vs. diffuse)
  - ⋆ source size limits
  - ⋆ structure, offsets, motion, drift with frequency
- also try pulsar data
- RS and LOFAR2.0

Summary

- fringes between KAIRA,LOFAR,LWA,NenuFAR !
  - ⋆ consistent phases on all baselines
  - ⋆ first transatlantic VLBI at 30 MHz ?
- need full polarisation calibration
- IPS(?) may be detrimental (can be studied)
- interesting substructure, how many sources?
- very preliminary, software not well tested
- not yet: pulsars, RS, LOFAR2.0, full calibration, . . .

https://fpra.mpifr-bonn.mpg.de/doku.php?id=projects:jupiter:index

Most important: Thanks to everybody involved!

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