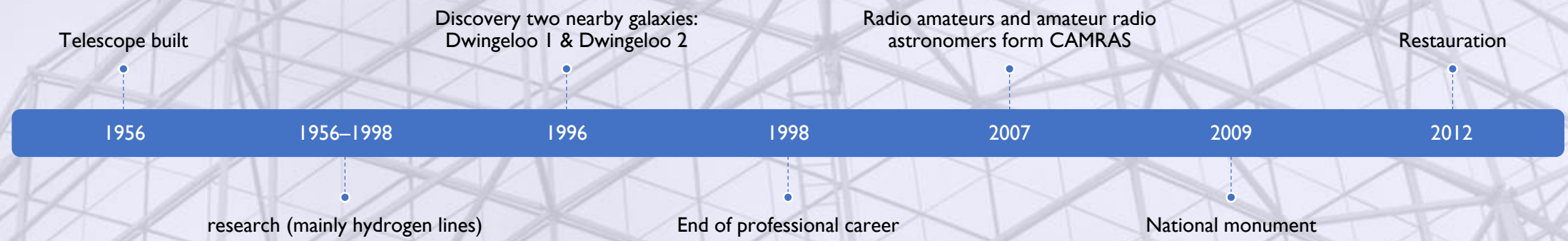
Recent observing techniques at the Dwingeloo telescope

Tammo Jan Dijkema & Thomas Telkamp, CAMRAS

EUCARA 2023, 17 September 2023

Intro Dwingeloo Telescope / CAMRAS



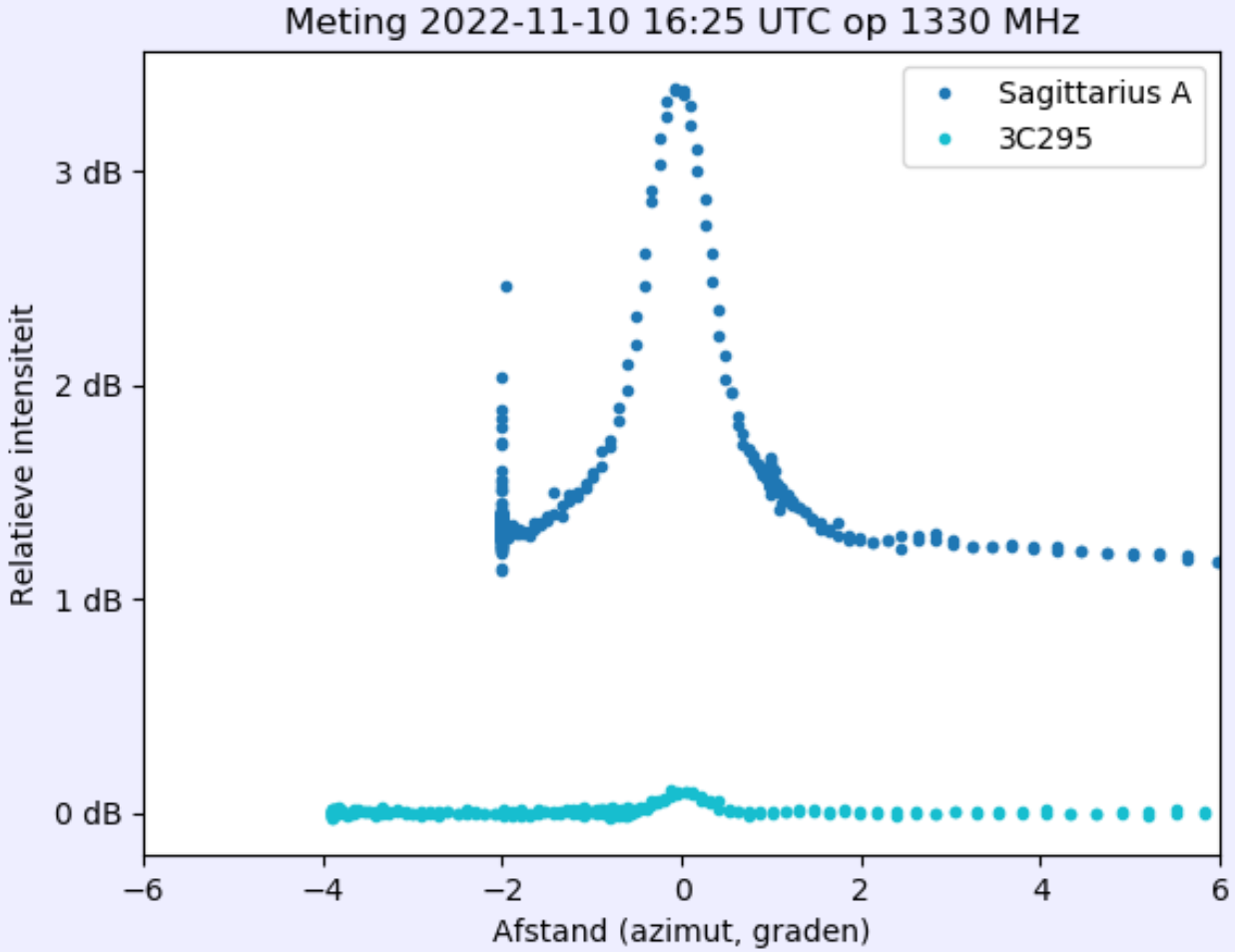

WWW.CAMRAS.NL
CAMRAS
DWINGELOO TELESCOOP

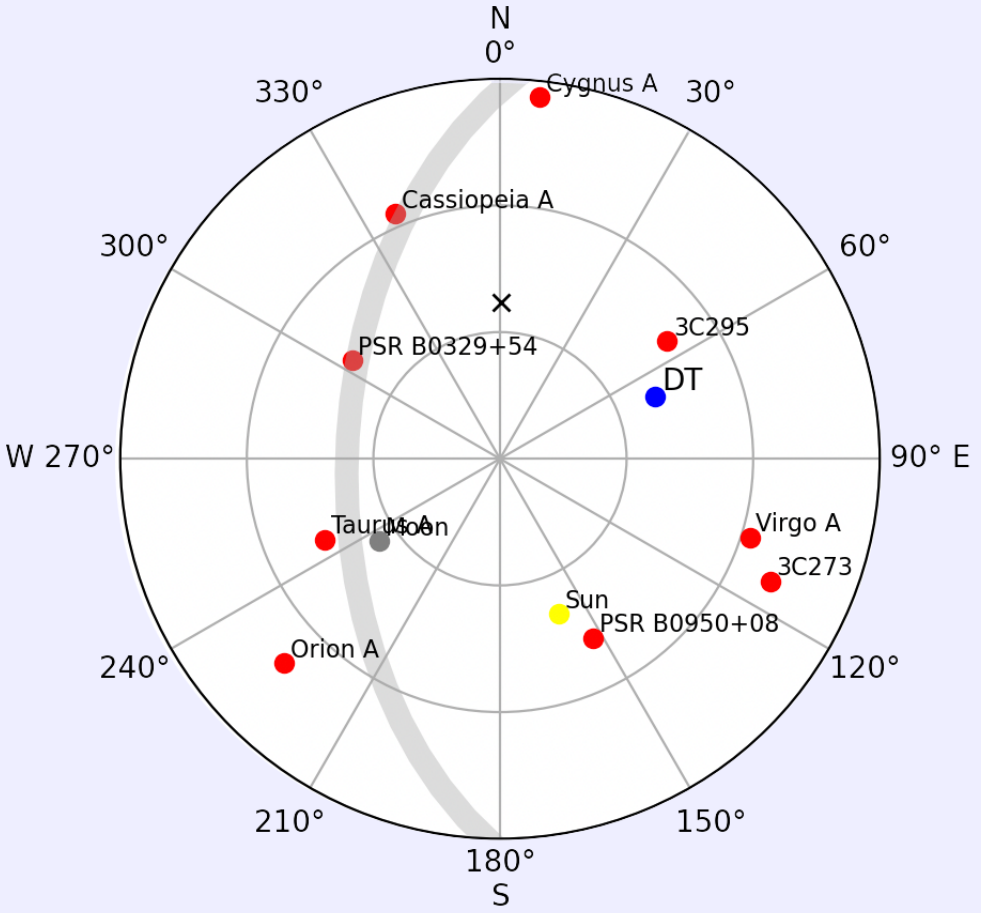
Things we observe with the DT

- Continuum sources, occultations
- Spectra: hydrogen line et al.
- Pulsars
- FRBs? Magnetars? (not yet)

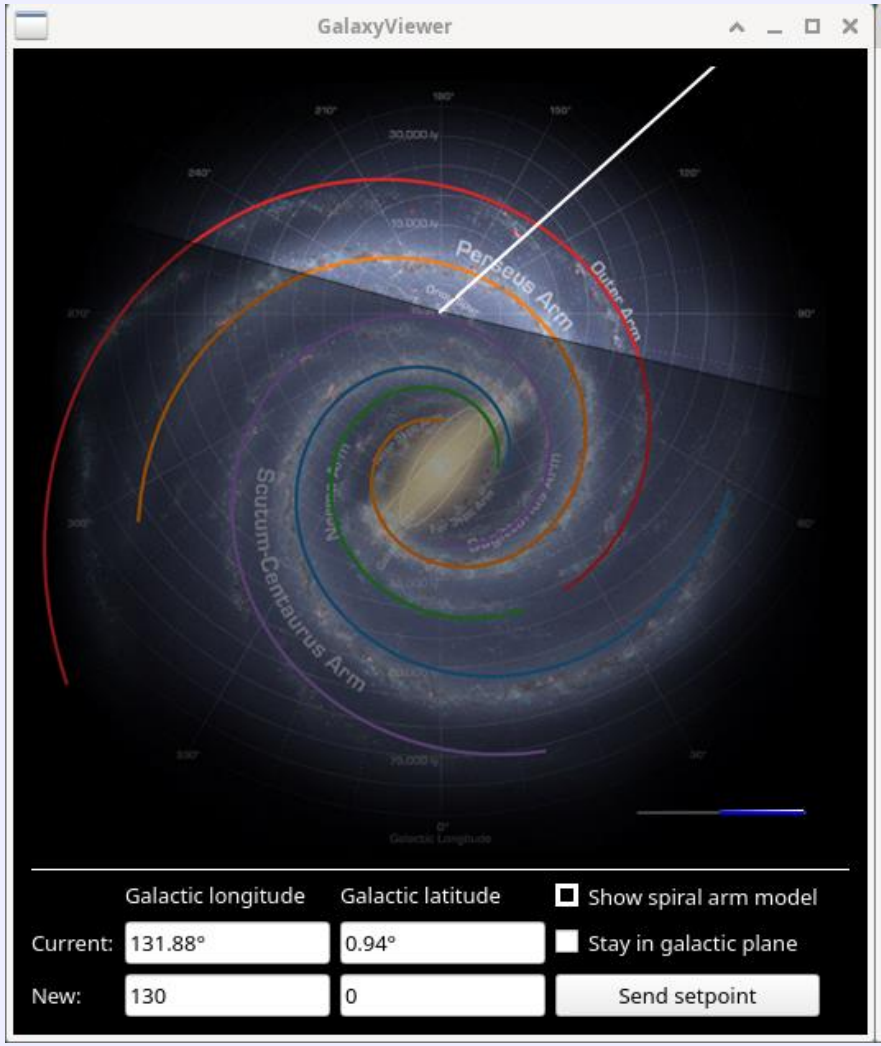
- Satellites
- Spacecraft
- SETI
- Amateur radio signals (EME, ATV, ...)

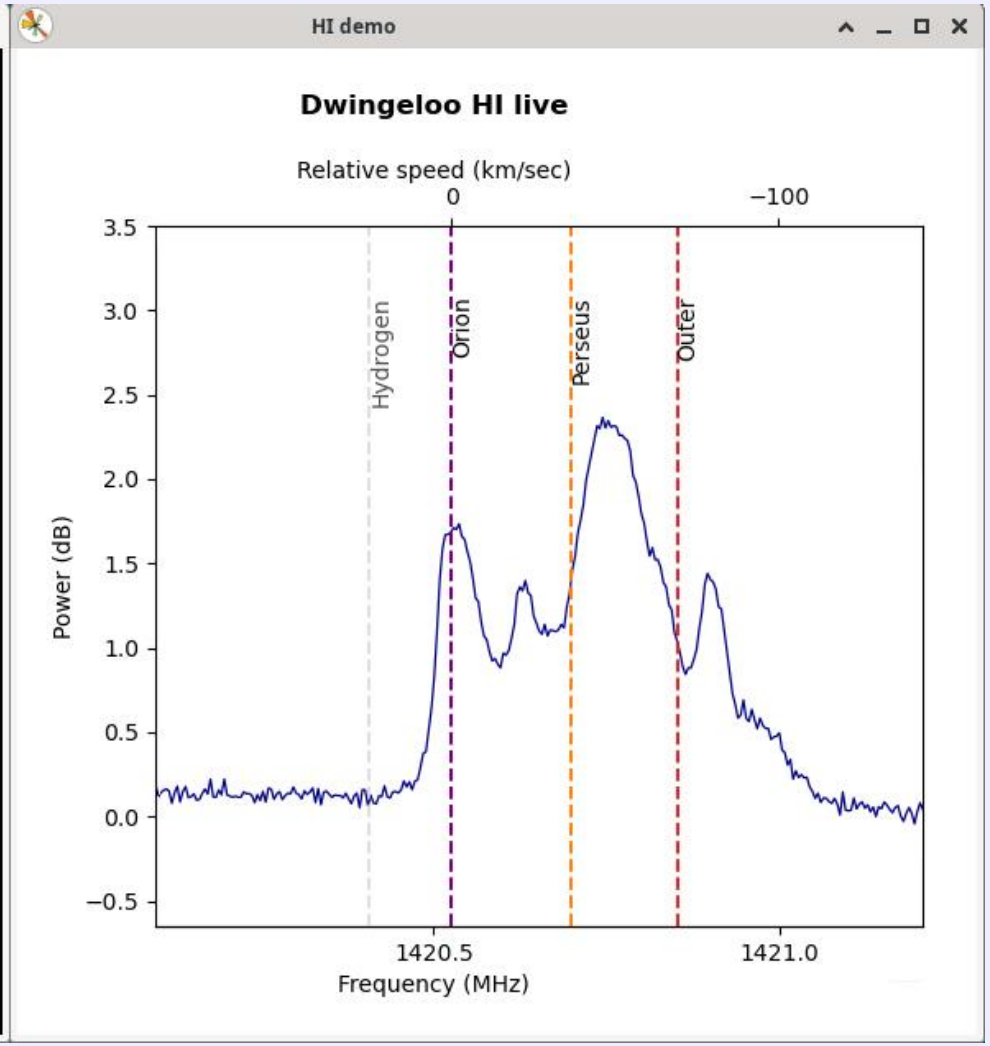
Cross scans / continuum demonstration



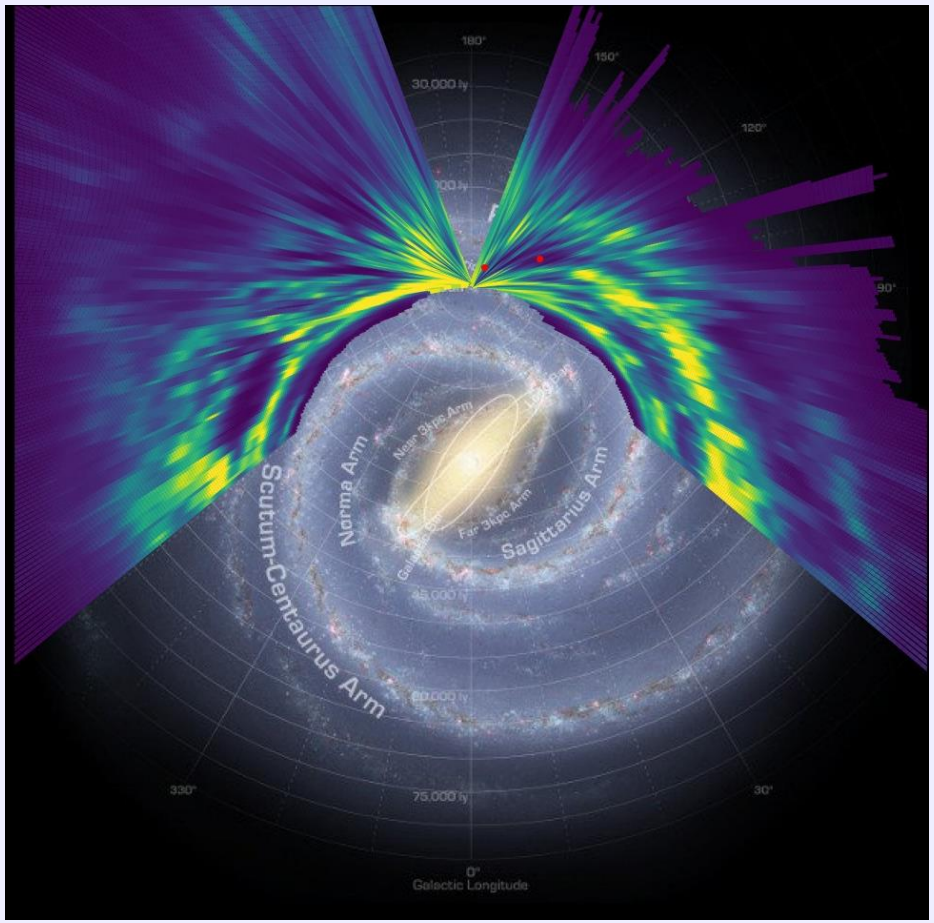


Hydrogen line demonstration



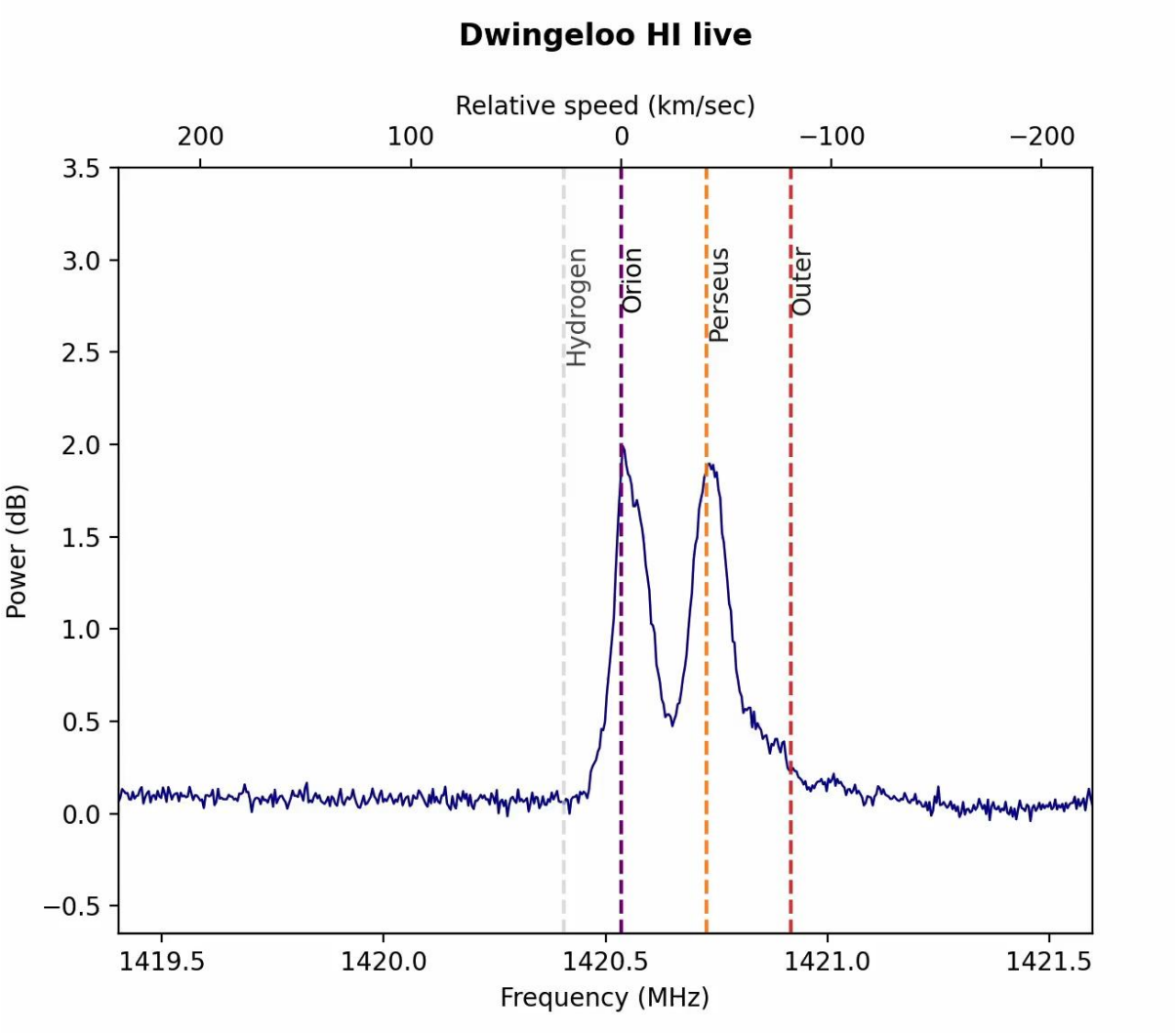


LAB mapped onto Milky way map



Projection following SALSA project

Hydrogen line demonstration



Absorption at Cassiopeia A

Dwingeloo 1 & 2, 1994

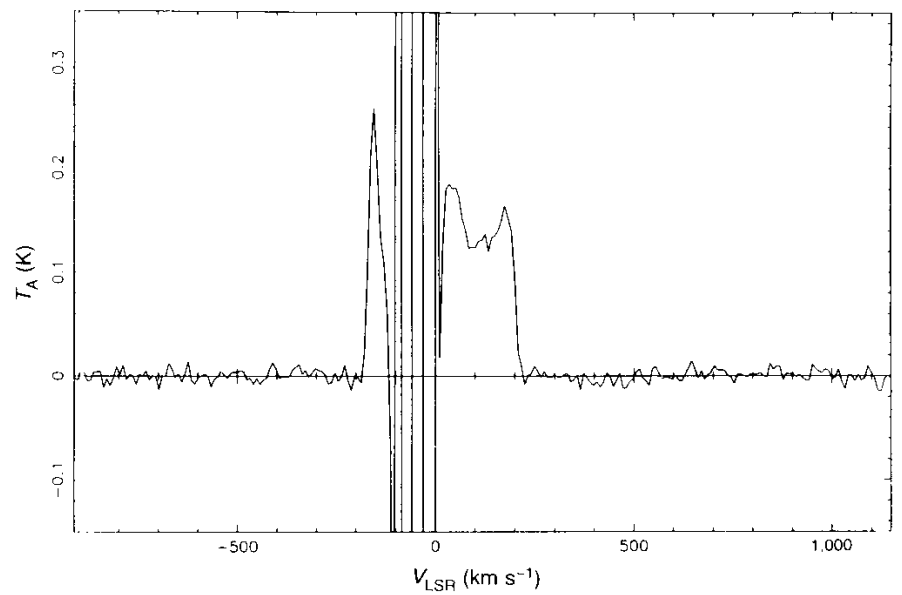
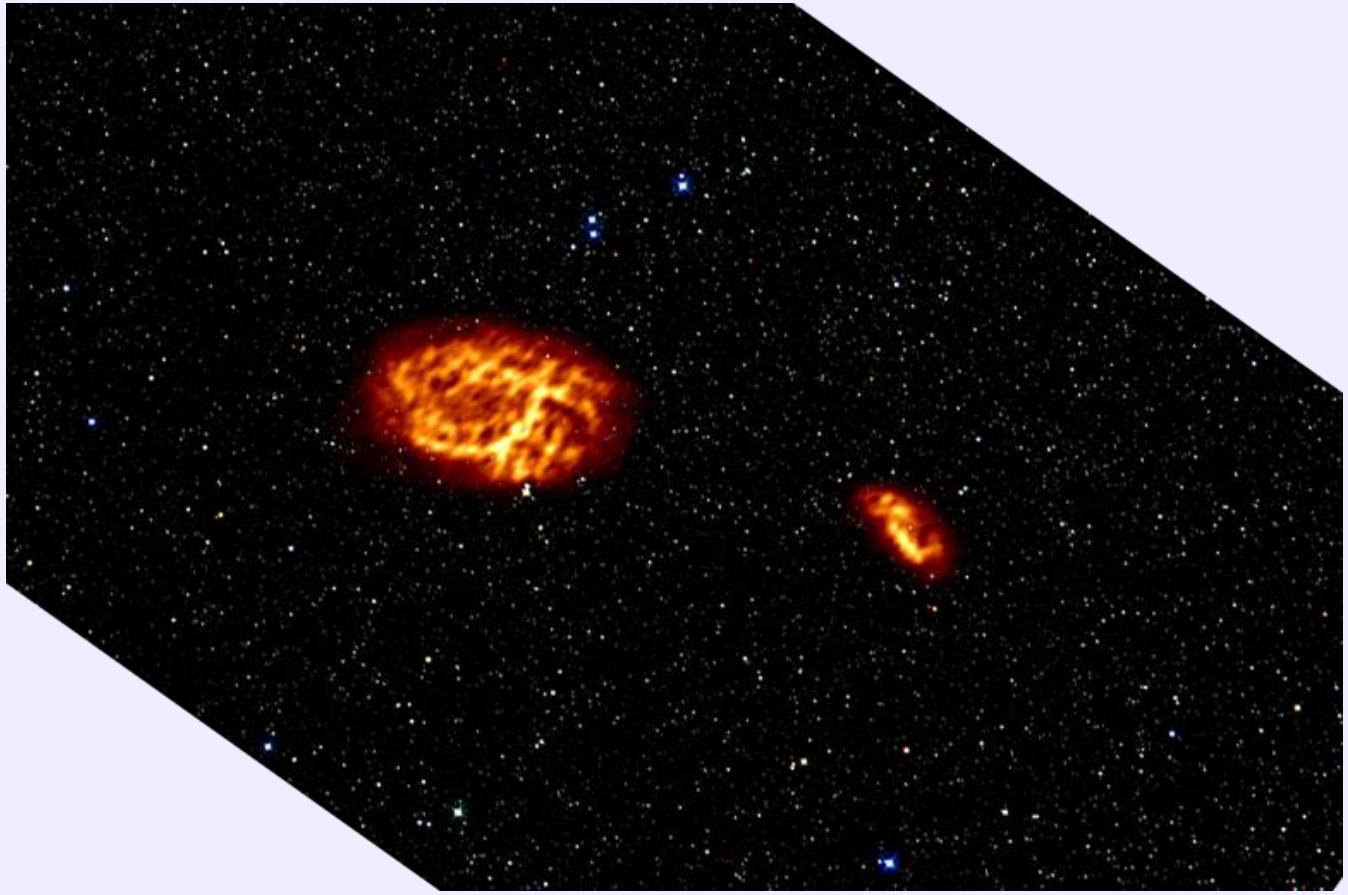


FIG. 1 Spectrum of H I emission from Dwingeloo 1 (Dw1) observed with the Dwingeloo 25-m radio-telescope (55-min integration). The radio-telescope has a 1,024-channel digital autocorrelator spectrometer and a system temperature of ~40 K. The velocity is relative to the local standard of rest, the intensity in terms of the antenna temperature, T_A (1 K ≡ 7.5 Jy). The instrumental profile (baseline) was minimized by position switching (on–off). The spectrum is displayed after one Hanning smoothing, and residual baseline subtraction. Dw1 has peak intensities at 1.4 and 1.2 Jy, and a full velocity-width (20%) of 200 km s^{-1}. Dw1 displays the classical 'double-horned' profile of an inclined spiral galaxy. Galactic emission disturbs this profile in the range $-170 < V_{LSR} < +40$ km s^{-1} (measured in both the 'on' and 'off' spectra, resulting in both positive and negative residuals in the 'on–off' spectrum).

R. Kraan-Korteweg

Using Dwingeloo Telescope

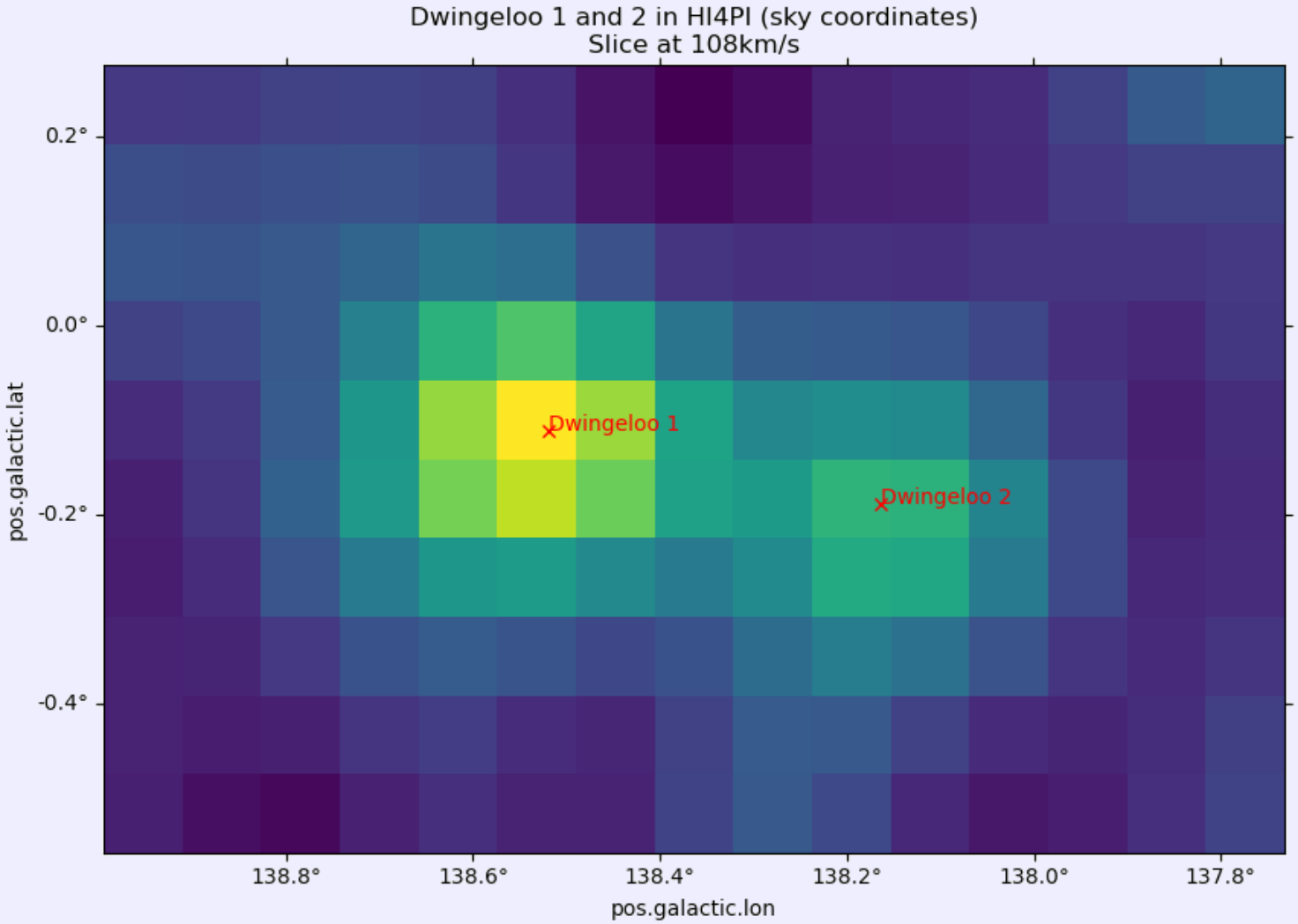
Dwingeloo 1 & 2, 2008



T. Oosterloo

Using WSRT

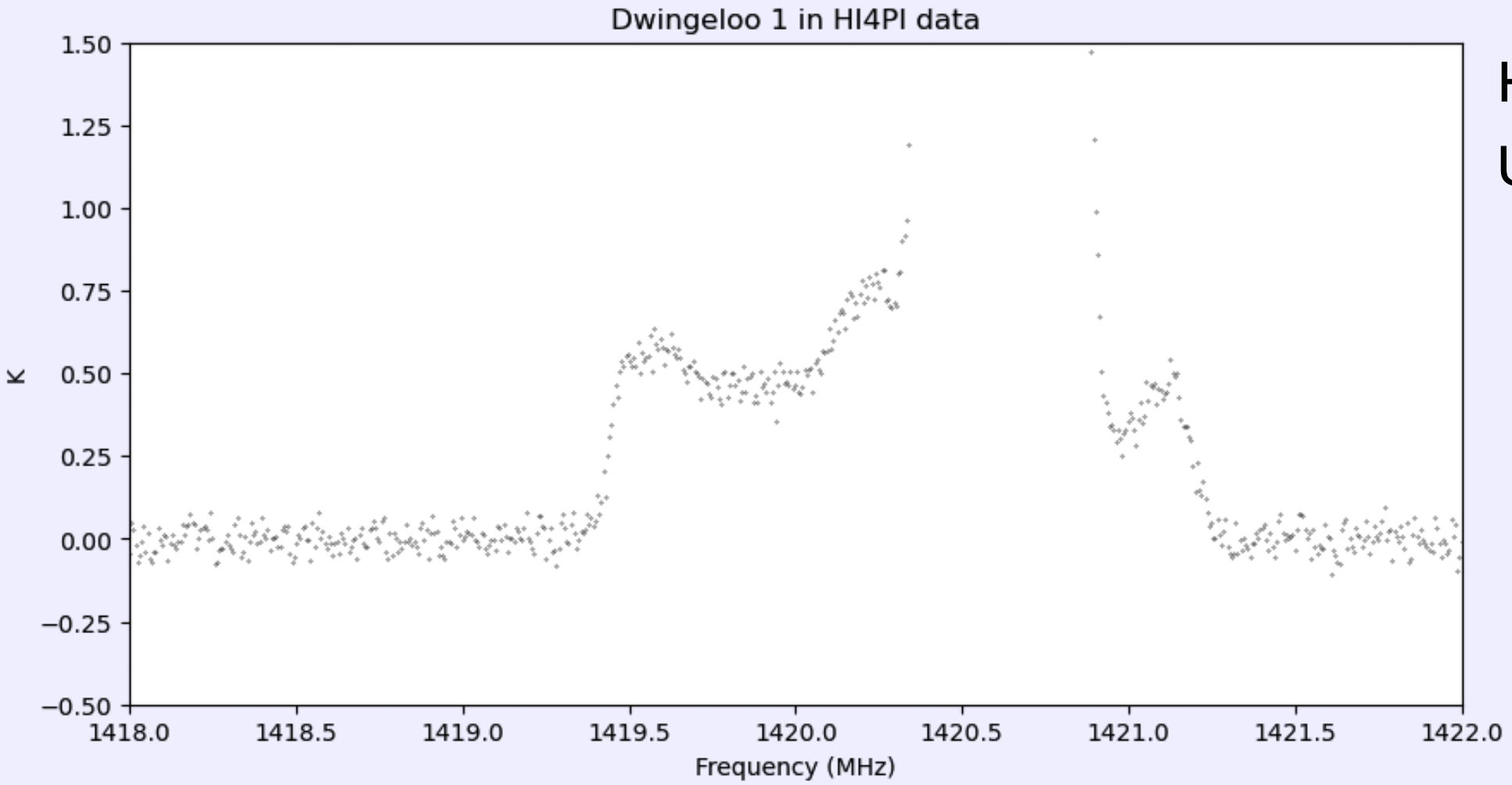
Dwingeloo 1 & 2, 2016



Kerp+ 2011,
Winkel+ 2016

Using Effelsberg

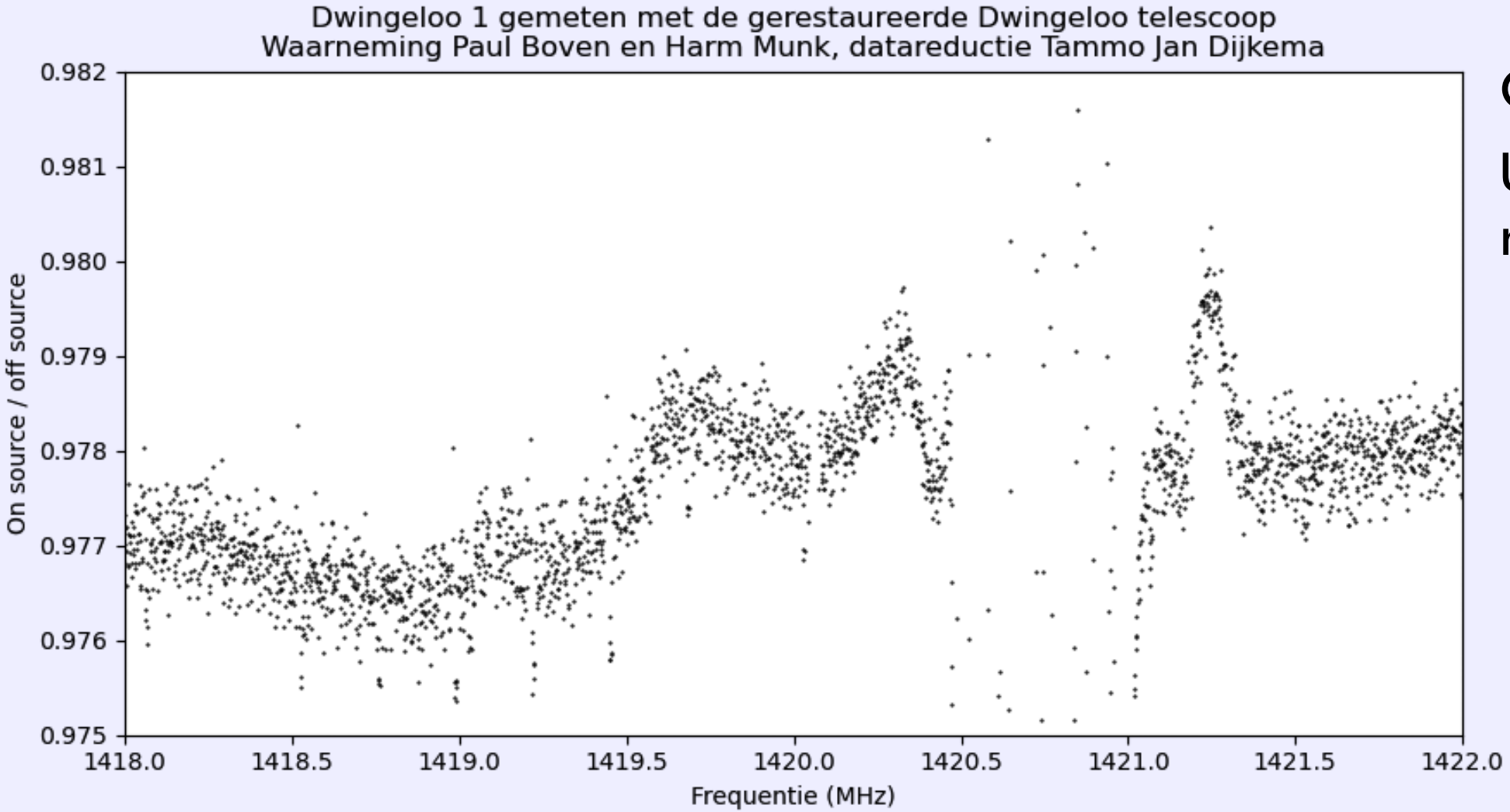
Dwingeloo 1 & 2, 2016



HI4PI collaboration

Using Effelsberg

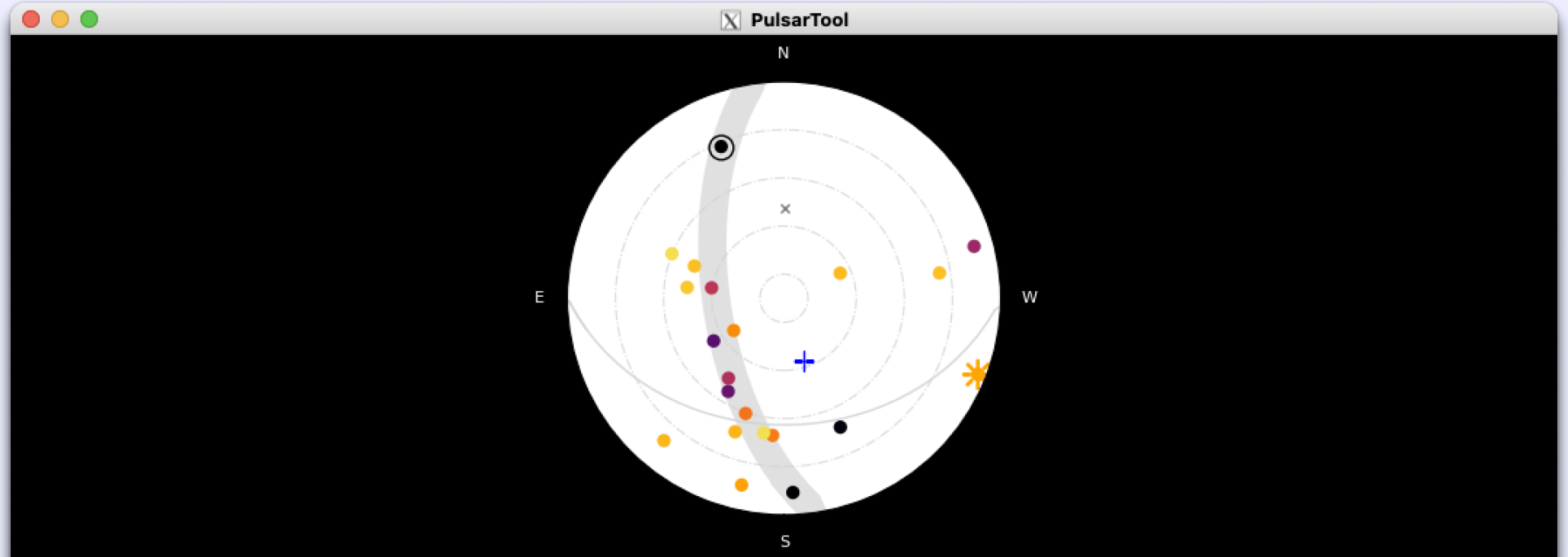
Dwingeloo 1 & 2, 2016 / 2023



CAMRAS

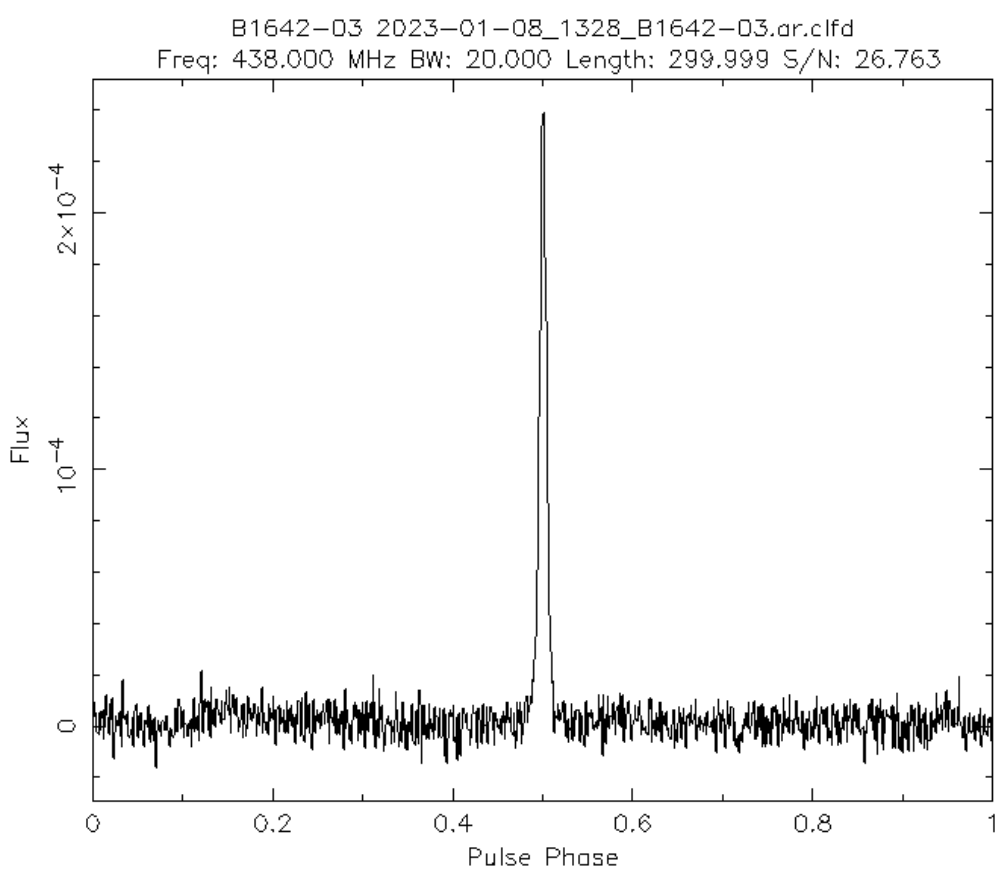
Using Dwingeloo radio telescope

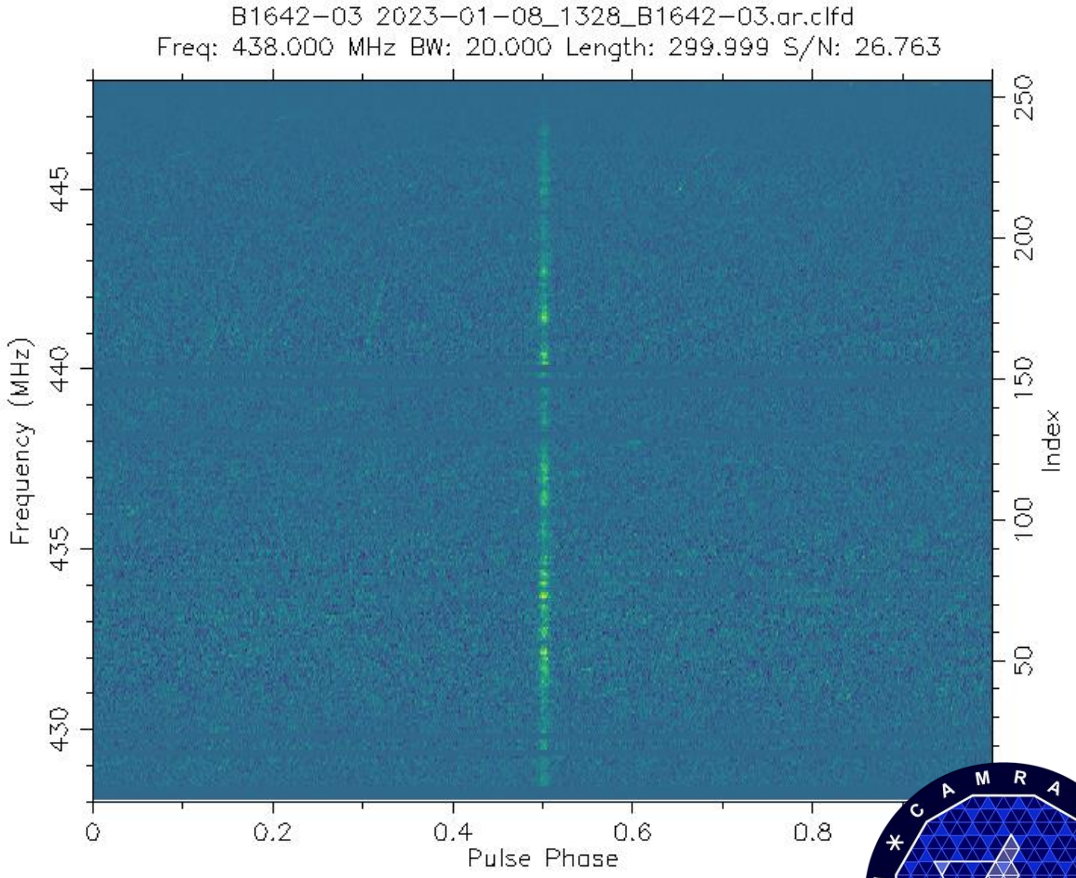
Pulsar tool



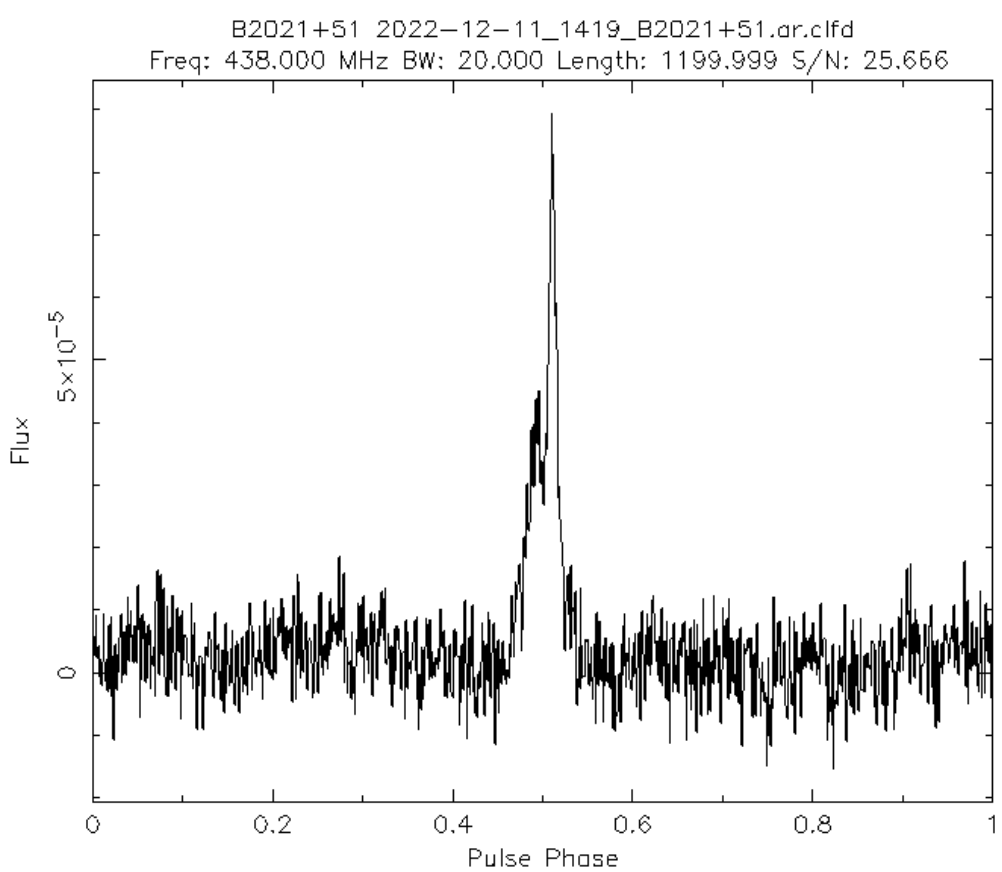
Name	S400	S1400	Period	DM	420MHz	1.4GHz	Elev.	Transit
B2111+46	230	19	1.01	141	detected		+60	>21:07 +84
B0628-28	206	23	1.24	34	detected		-66	<06:27 + 9
B1859+03	165	4	0.66	402			+40	>18:56 +41
B1818-04	157	6	0.60	84			+33	>18:15 +33
B1946+35	145	8	0.72	129	detected		+65	>19:42 +73
B1857-26	131	13	0.61	38	detected		+10	>18:55 +11

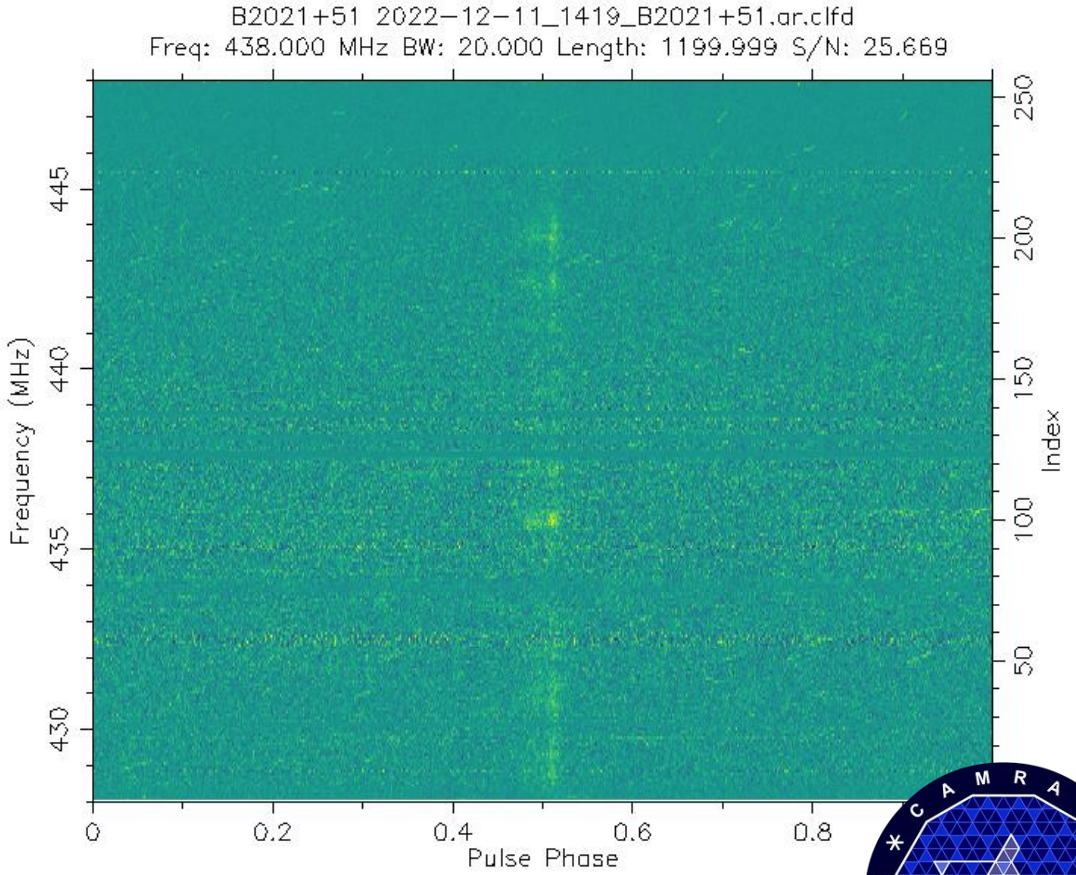
Folded pulsar B1642-03

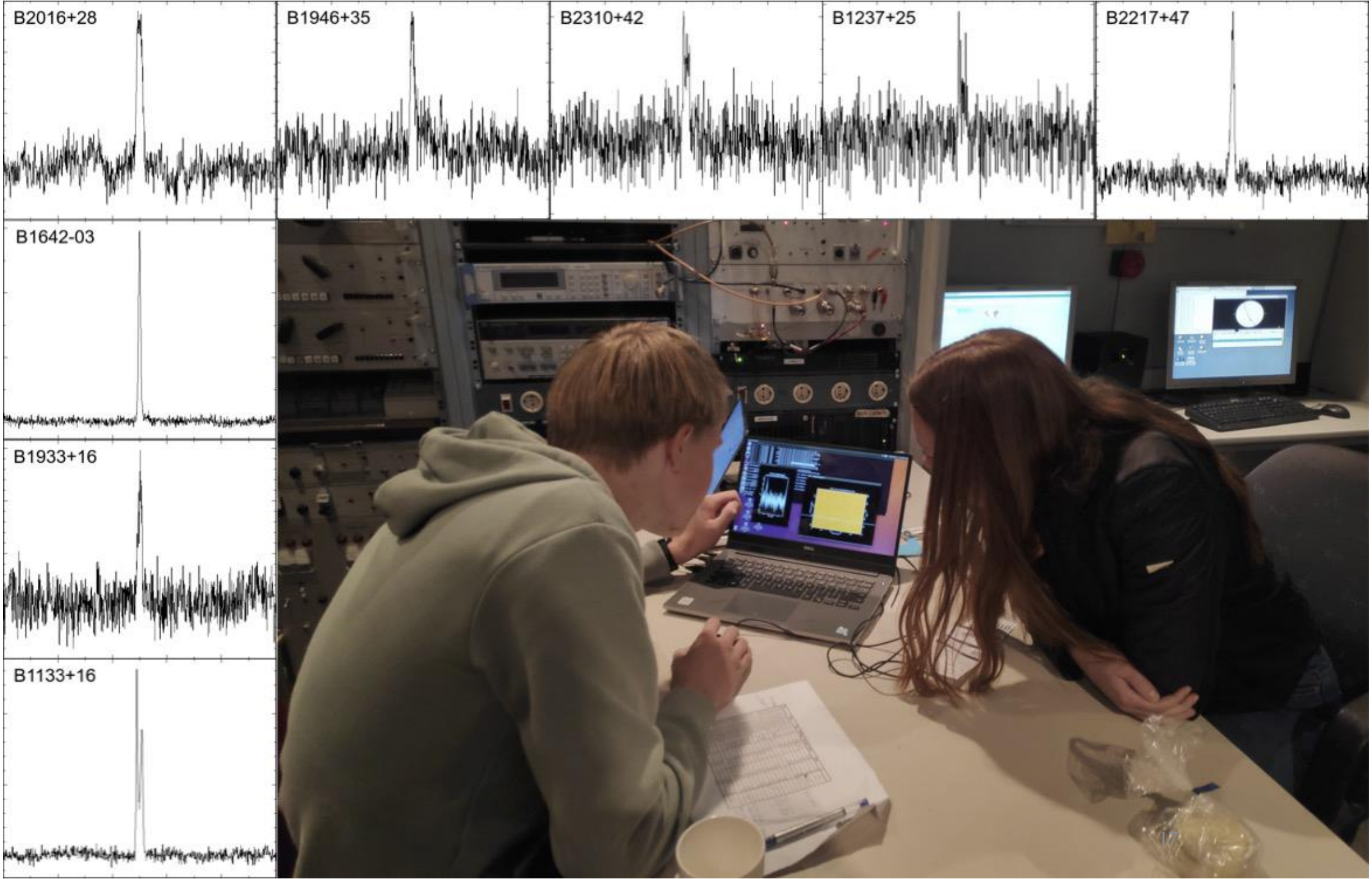




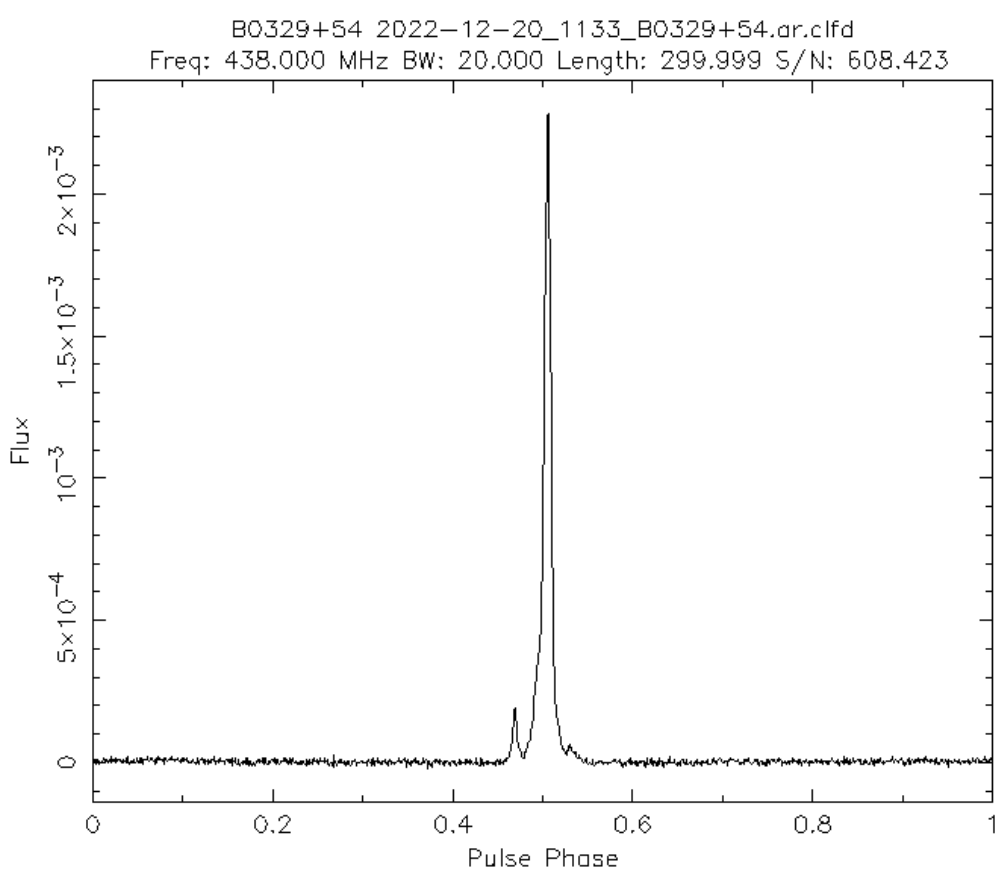
Folded pulsar B0202I+5I

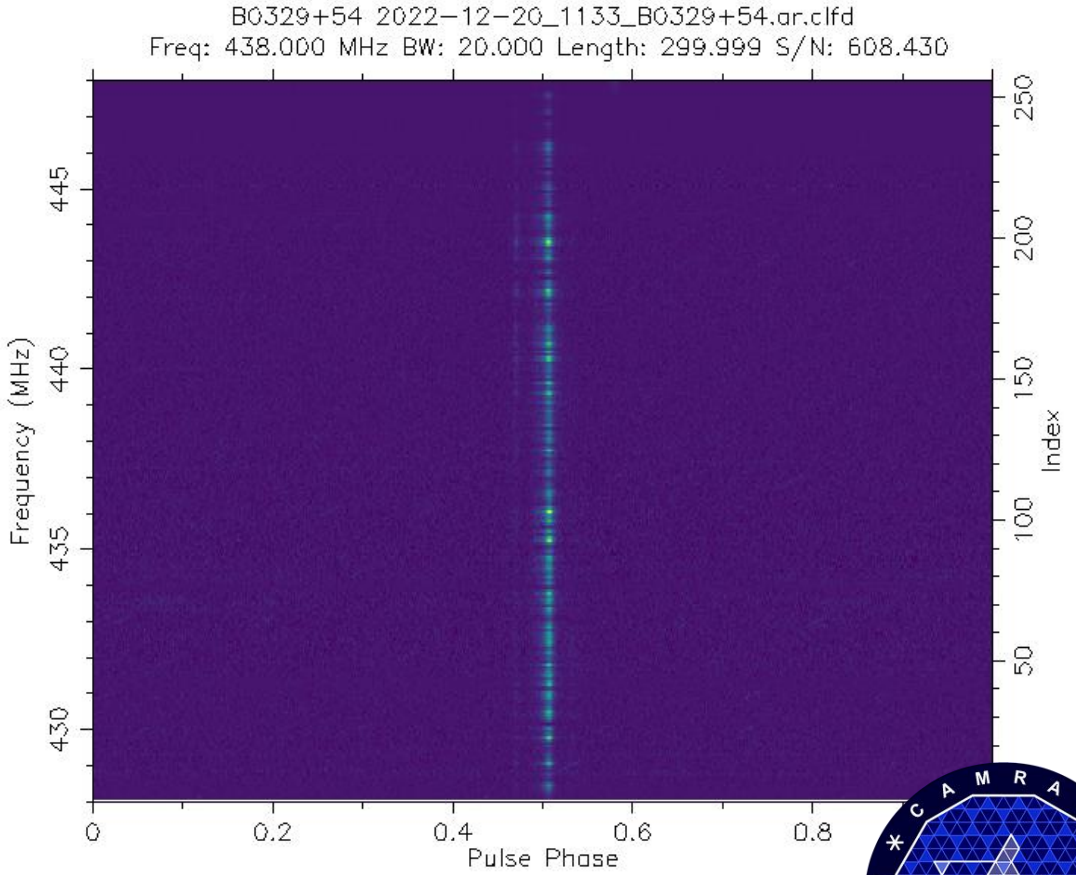




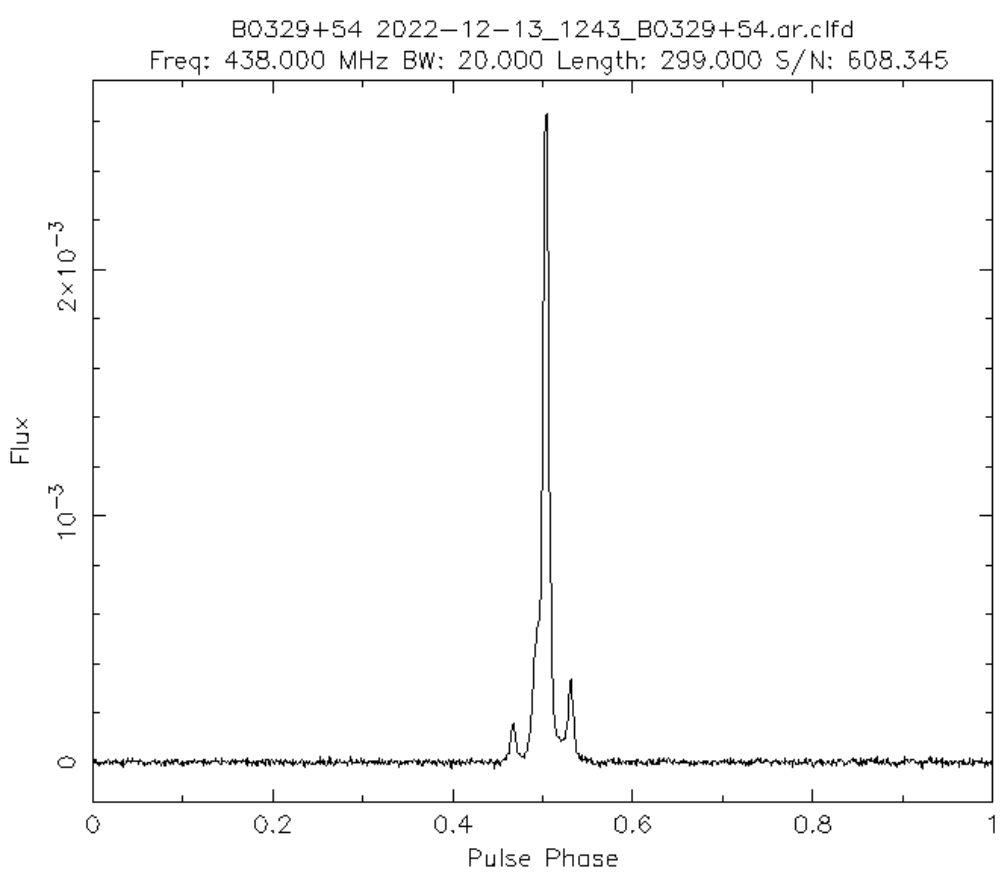

B2016+28
B1946+35
B2310+42
B1237+25
B2217+47
B1642-03
B1933+16
B1133+16

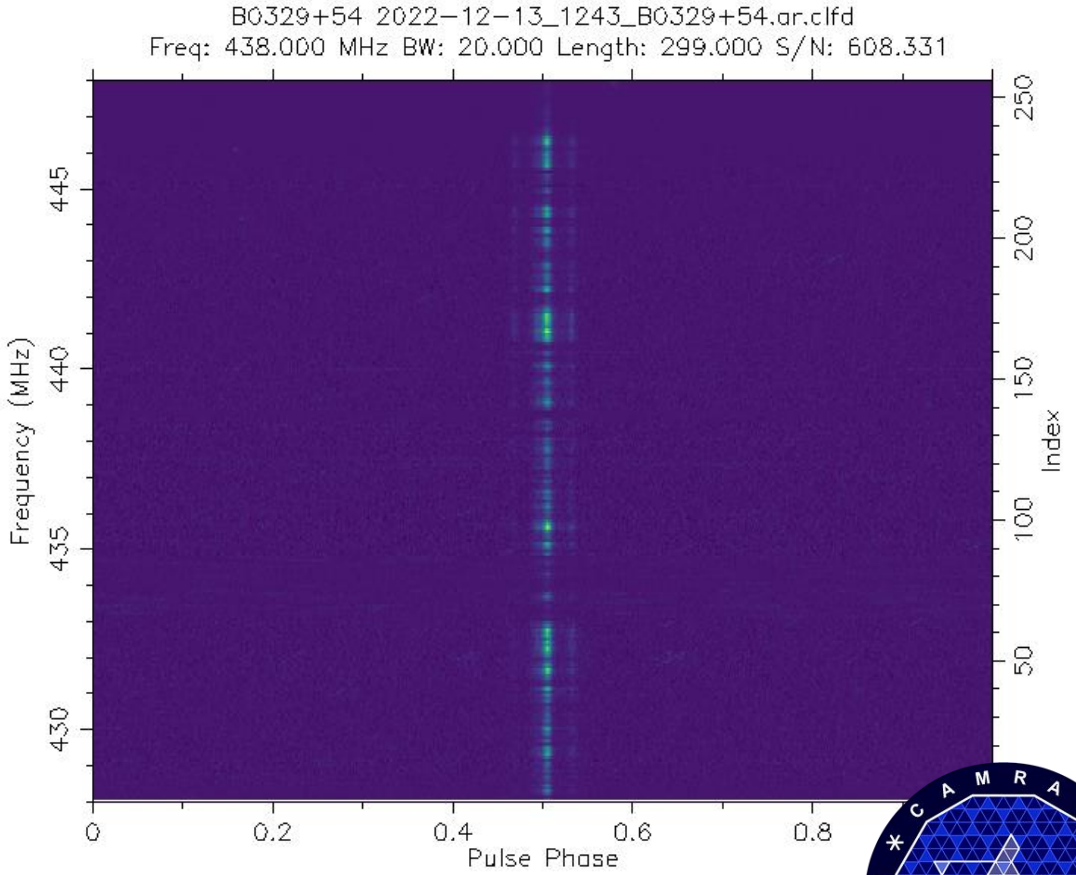
Folded pulsar B0329+54





Folded pulsar B0329+54





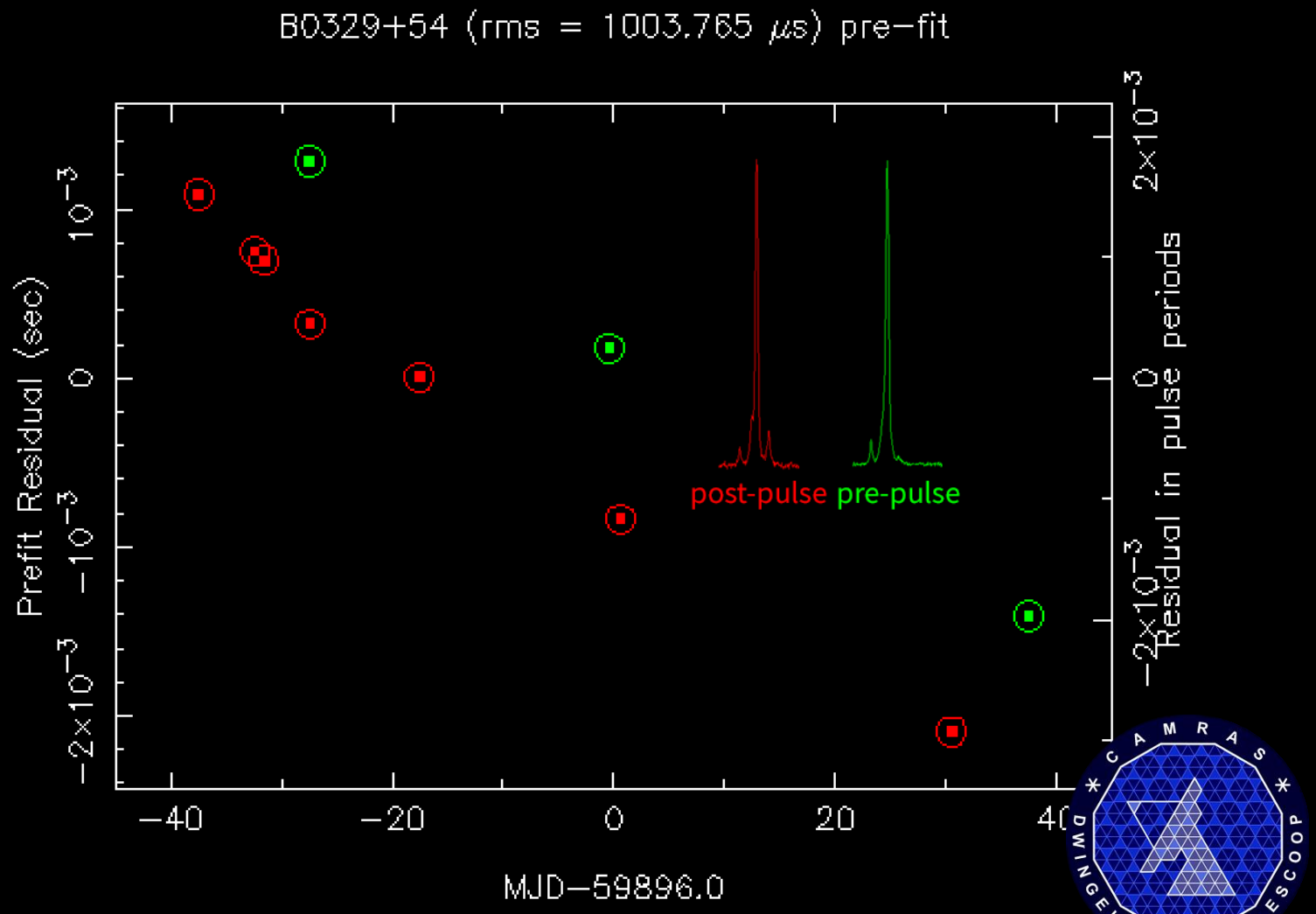
Pulsar timing, 80 days

dada

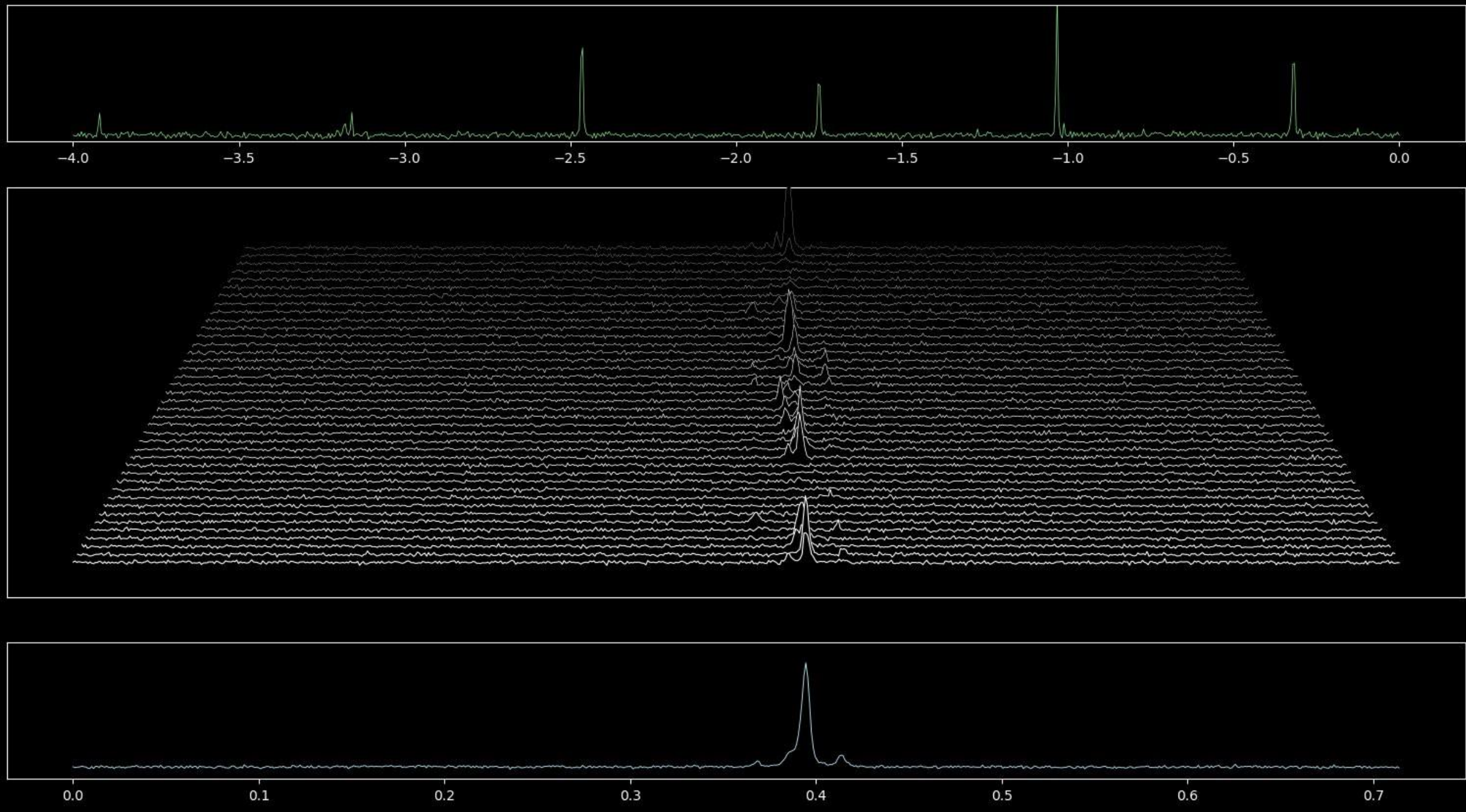
dspsr

psrchive

tempo2

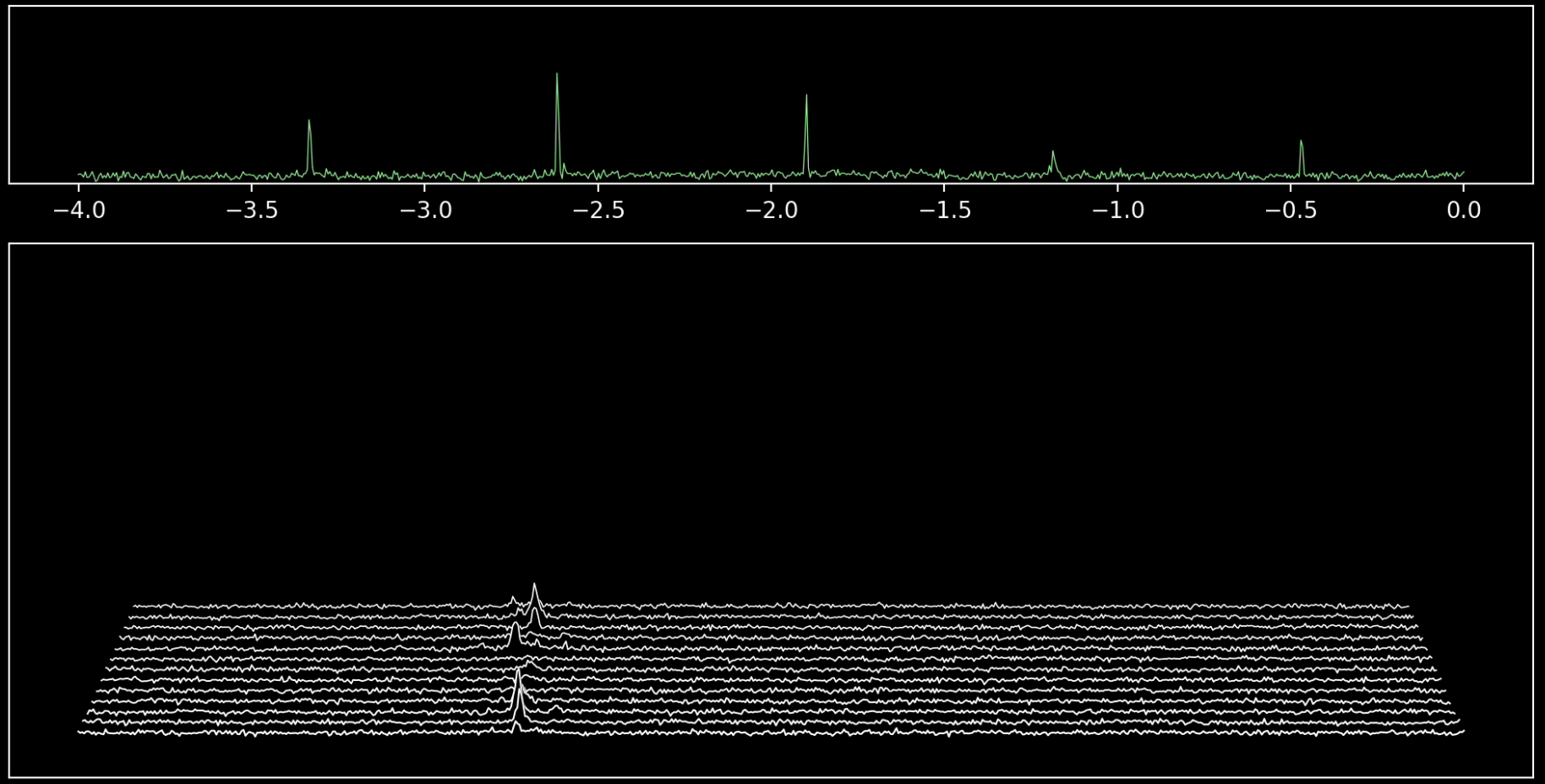


Pulsar **B0329+54**



Pulsar **B0329+54**

H V H+V exit reset

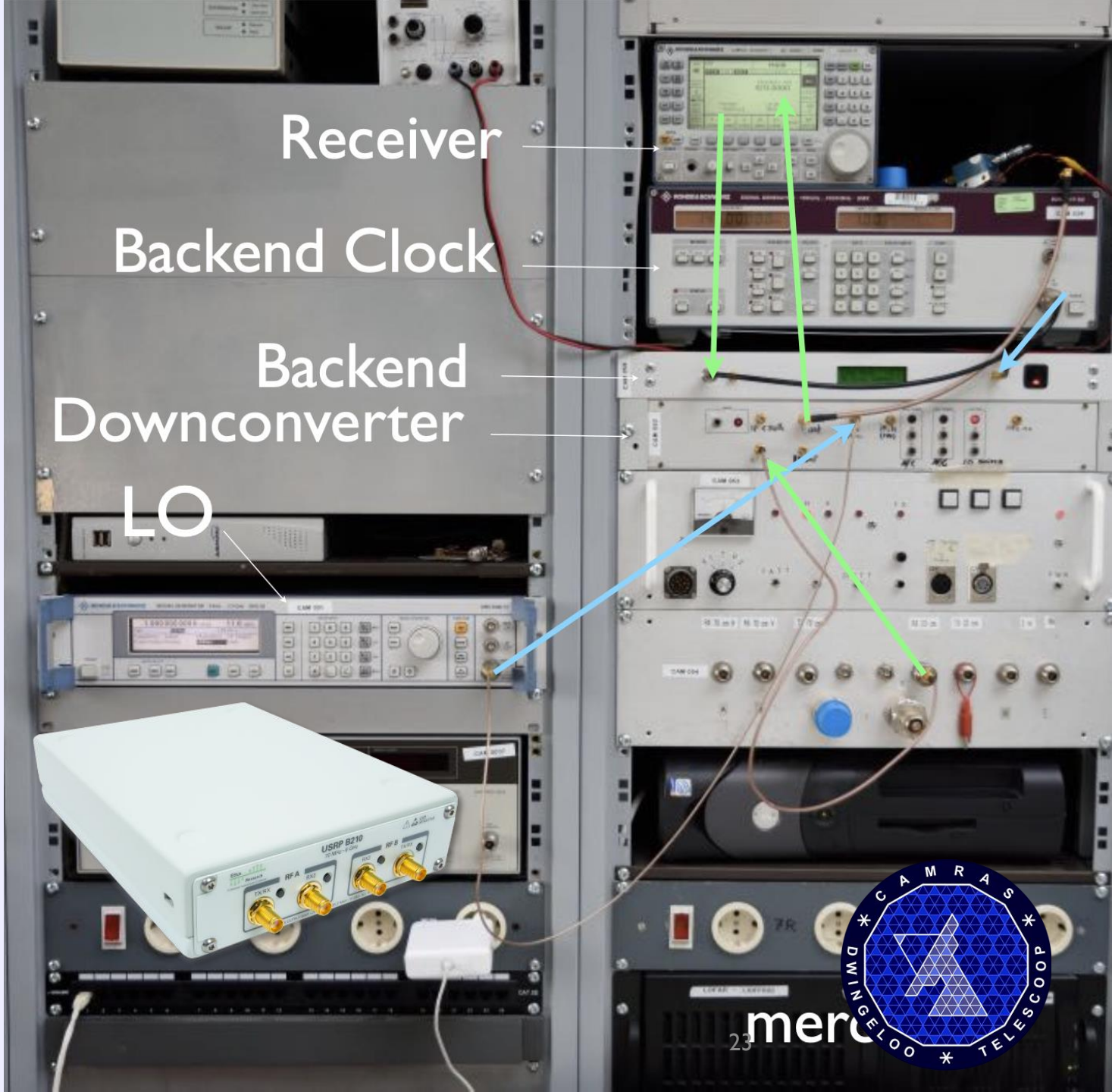


CAMRAS DWINGELOO TELESCOOP

SDR change

- Eucara 2016:
  "Dwingeloo goes SDR"

- Eucara 2023:
  "Dwingeloo really goes SDR"



Raw IQ files

URESAT-CAMRAS-2023-08-20T11:59:18-_436.886MHz_1.00Msps_ci16_le.raw

```
793f c5b8 adbb a637 62e3 beb8 a2b6 40b8
7354 1ab8 136f 32b9 5e3a 2538 3368 3638
00d6 a138 2fa8 94b8 de4d 1db8 f4e5 2838
d650 93b8 c526 2d37 1305 f0b7 49cd a638
7bf4 e0b8 be52 3c39 6e6b c4b8 d6f5 3437
7410 4139 3ae8 1a39 f61d f538 7973 0638
62cd 9e37 ac6a 4ab7 e028 9bb8 f07b 31b8
c674 7cb8 7c3e 1038 b9bc c138 51ce 3338
c5b4 9c37 0c95 6b38 f8e8 9738 301c 95b7
58f5 8237 d517 9ab8 6fb3 62b8 6d63 0639
7410 4139 3ae8 1a39 f61d f538 7973 0638
62cd 9e37 ac6a 4ab7 e028 9bb8 f07b 31b8
c674 7cb8 7c3e 1038 b9bc c138 51ce 3338
c5b4 9c37 0c95 6b38 f8e8 9738 301c 95b7
58f5 8237 d517 9ab8 6fb3 62b8 6d63 0639
c5b4 9c37 0c95 6b38 f8e8 9738 301c 95b7
```

SigMF

(trivial to read into python)

URESAT-2023-08-20.sigmf-meta

```
{
  "global": {
    "core:version": "1.0.0",
    "core:recorder": "vrt_to_sigmf",
    "core:sample_rate": 1000000,
    "core:datatype": "ci16_le",
    "core:author": "CAMRAS, TT",
    "core:description": "URESAT-1",
    "dt:datetime": "2023-08-20T11:59:18.800000",
    "dt:pointing:active_tracker": "sattracker",
    "dt:pointing:tracking_enabled": "true",
    "dt:pointing:refraction": "true",
    "dt:pointing:dt_model": "true",
    "dt:focusbox_position_mm": 459,
    "vrt:rx_gain": 40,
    "vrt:bandwidth": 56000000,
    "vrt:reference": "external",
    "vrt:time_source": "internal",
    "vrt:stream_id": 1,
    "vrt:channel": 0
  },
  "annotations": [],
  "captures": [
    {
      "core:sample_start": 0,
      "core:frequency": 436886000,
      "core:datetime": "2023-08-20T11:59:18.580039"
    }
  ]
}
```

URESAT-2023-08-20.sigmf-data

```
793f c5b8 adbb a637 62e3 beb8 a2b6 40b8
7354 1ab8 136f 32b9 5e3a 2538 3368 3638
00d6 a138 2fa8 94b8 de4d 1db8 f4e5 2838
d650 93b8 c526 2d37 1305 f0b7 49cd a638
7bf4 e0b8 be52 3c39 6e6b c4b8 d6f5 3437
7410 4139 3ae8 1a39 f61d f538 7973 0638
62cd 9e37 ac6a 4ab7 e028 9bb8 f07b 31b8
c674 7cb8 7c3e 1038 b9bc c138 51ce 3338
c5b4 9c37 0c95 6b38 f8e8 9738 301c 95b7
58f5 8237 d517 9ab8 6fb3 62b8 6d63 0639
7410 4139 3ae8 1a39 f61d f538 7973 0638
62cd 9e37 ac6a 4ab7 e028 9bb8 f07b 31b8
c674 7cb8 7c3e 1038 b9bc c138 51ce 3338
c5b4 9c37 0c95 6b38 f8e8 9738 301c 95b7
58f5 8237 d517 9ab8 6fb3 62b8 6d63 0639
c5b4 9c37 0c95 6b38 f8e8 97
```

Raw UDP

```
793f c5b8 adbb a637 62e3 beb8 a2b6 40b8
7354 1ab8 136f 32b9 5e3a 2538 3368 3638
00d6 a138 2fa8 94b8 de4d 1db8 f4e5 2838
d650 93b8 c526 2d37 1305 f0b7 49cd a638
7bf4 e0b8 be52 3c39 6e6b c4b8 d6f5 3437
7410 4139 3ae8 1a39 f61d f538 7973 0638
62cd 9e37 ac6a 4ab7 e028 9bb8 f07b 31b8
c674 7cb8 7c3e 1038 b9bc c138 51ce 3338
c5b4 9c37 0c95 6b38 f8e8 9738 301c 95b7
58f5 8237 d517 9ab8 6fb3 62b8 6d63 0639
7410 4139 3ae8 1a39 f61d f538 7973 0638
62cd 9e37 ac6a 4ab7 e028 9bb8 f07b 31b8
c674 7cb8 7c3e 1038 b9bc c138 51ce 3338
c5b4 9c37 0c95 6b38 f8e8 9738 301c 95b7
58f5 8237 d517 9ab8 6fb3 62b8 6d63 0639
c5b4 9c37 0c95 6b38 f8e8 9738 301c 95b7
```

VRT stream

```
frequency: 433668000
sample rate: 1000000
gain: 52
```

```
793f c5b8 adbb a637 62e3 beb8 a2b6 40b8
7354 1ab8 136f 32b9 5e3a 2538 3368 3638
00d6 a138 2fa8 94b8 de4d 1db8 f4e5 2838
d650 93b8 c526 2d37 1305 f0b7 49cd a638
7bf4 e0b8 be52 3c39 6e6b c4b8 d6f5 3437
7410 4139 3ae8 1a39 f61d f538 7973 0638
```

```
frequency: 433668000
sample rate: 1000000
gain: 52
```

```
telescope azimuth: 42.600deg
telescope elevation: 10.003deg
```

```
62cd 9e37 ac6a 4ab7 e028 9bb8 f07b 31b8
c674 7cb8 7c3e 1038 b9bc c138 51ce 3338
c5b4 9c37 0c95 6b38 f8e8 9738 301c 95b7
58f5 8237 d517 9ab8 6fb3 62b8 6d63 0639
7410 4139 3ae8 1a39 f61d f538 7973 0638
62cd 9e37 ac6a 4ab7 e028 9bb8 f07b 31b8
```

How to get a VRT stream

- usrp_to_vrt
- rtl_to_vrt
- rfspace_to_vrt

- sigmf_to_vrt
- vrtfile_to_vrt

vrt-iq-tools

console

SDR

usrp_to_vrt

rtl_to_vrt

rfspace_to_vrt

sigmf_to_vrt

zmq

vrt_to_gnuradio

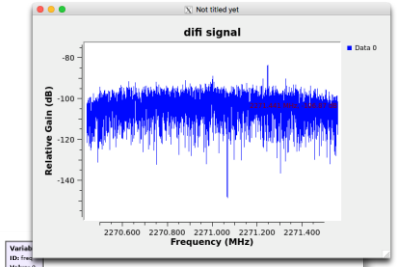
vrt_to_sigmf

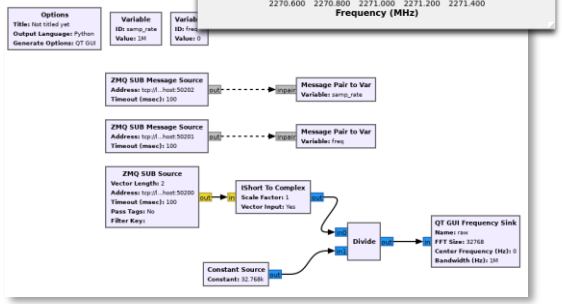
vrt_gnuplot

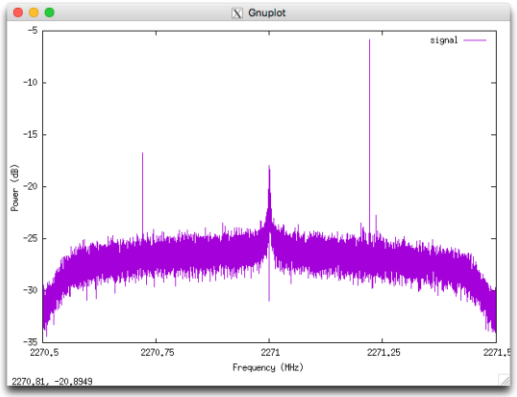
vrt_to_dada

vrt_fftmax

etc.



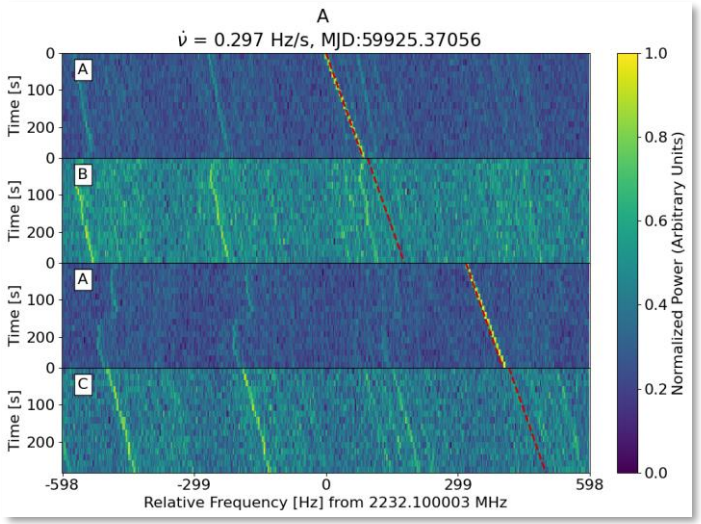


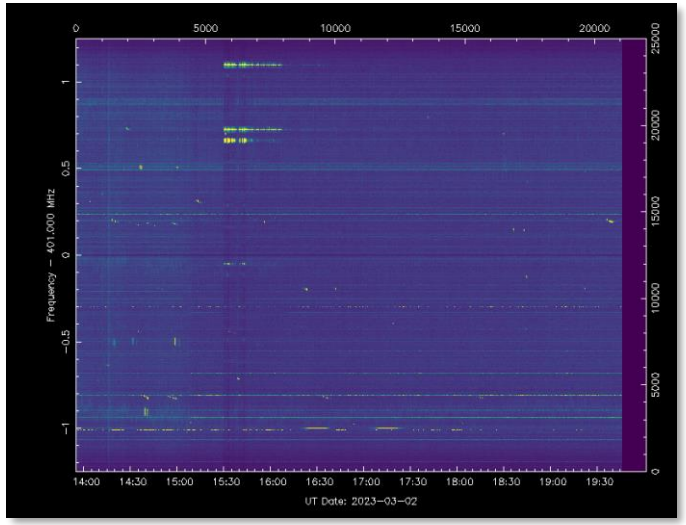



```
# DIFI Context:
#    Sample Rate [samples per second]: 1000000
#    RF Freq [Hz]: 2271000000
#    Bandwidth [Hz]: 0
#    Gain [dB]: 0
#    Ref lock: 0
#    Time cal: 0
# First frame: 10000 samples, 1663493057 full secs, 0.701662000 frac secs
timestamp, frequency, power
1663493058.701663000, 2271220582, 16.433
1663493059.701663000, 2271220582, 15.966
1663493060.701663000, 2271220582, 13.740
1663493061.701663000, 2271220581, 14.262
1663493062.701663000, 2271220581, 16.446
1663493063.701663000, 2271220581, 14.340
1663493064.701663000, 2271220580, 16.068
1663493065.701663000, 2271220579, 16.032
```

What to do with a VRT stream

- Filterbank (SETI)
- Pulsar
- Spectrum (= filterbank)
- SigMF
- FIFO (e.g. for Gqrx)
- rtl_tcp
- DADA (pulsar, psrchive)
- STRF (Cees Bassa)
- Gnuplot
- GnuRadio
- FFTmax and FFTmax_quad
- ‘void’
- control_vrt

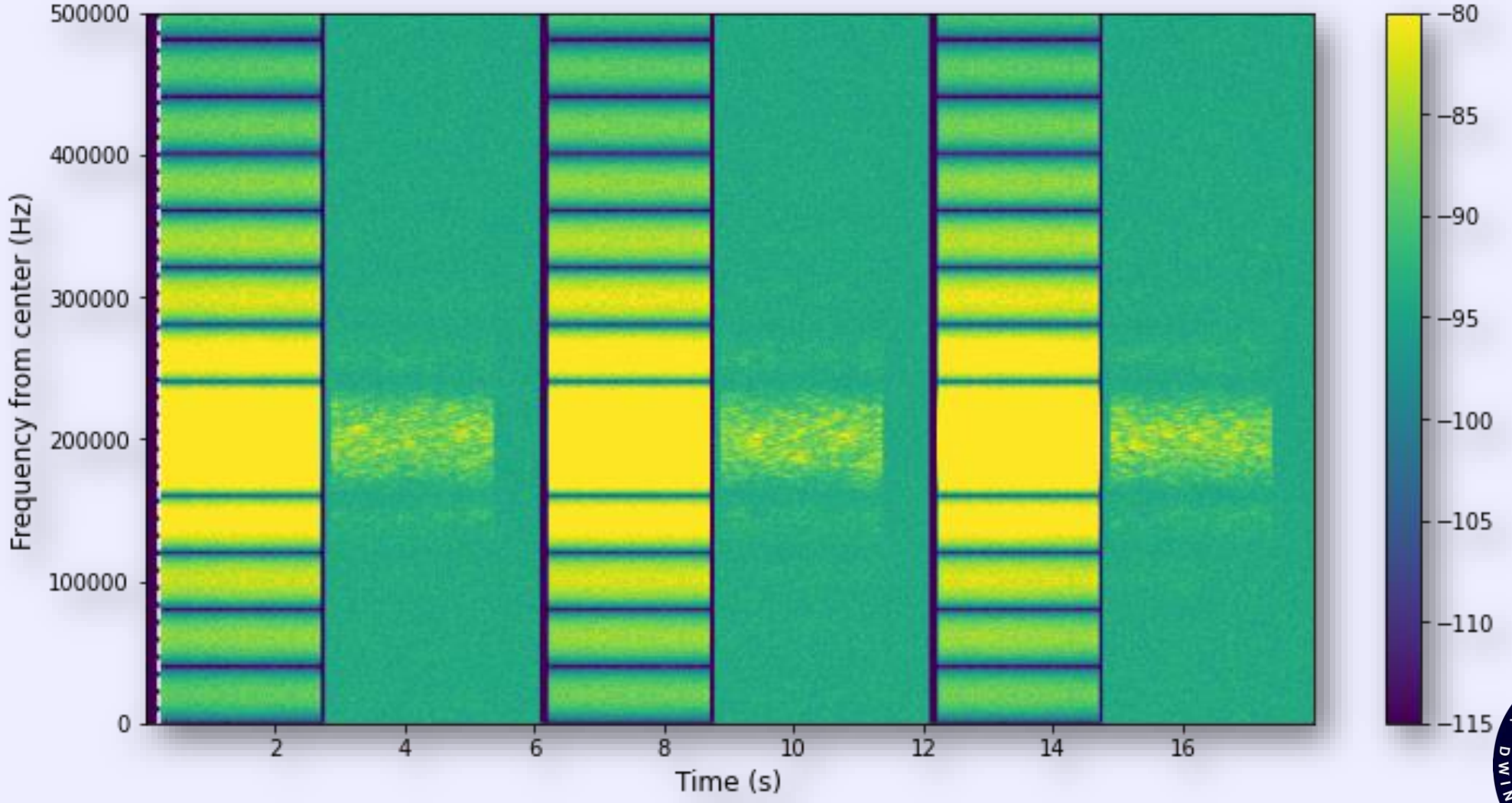


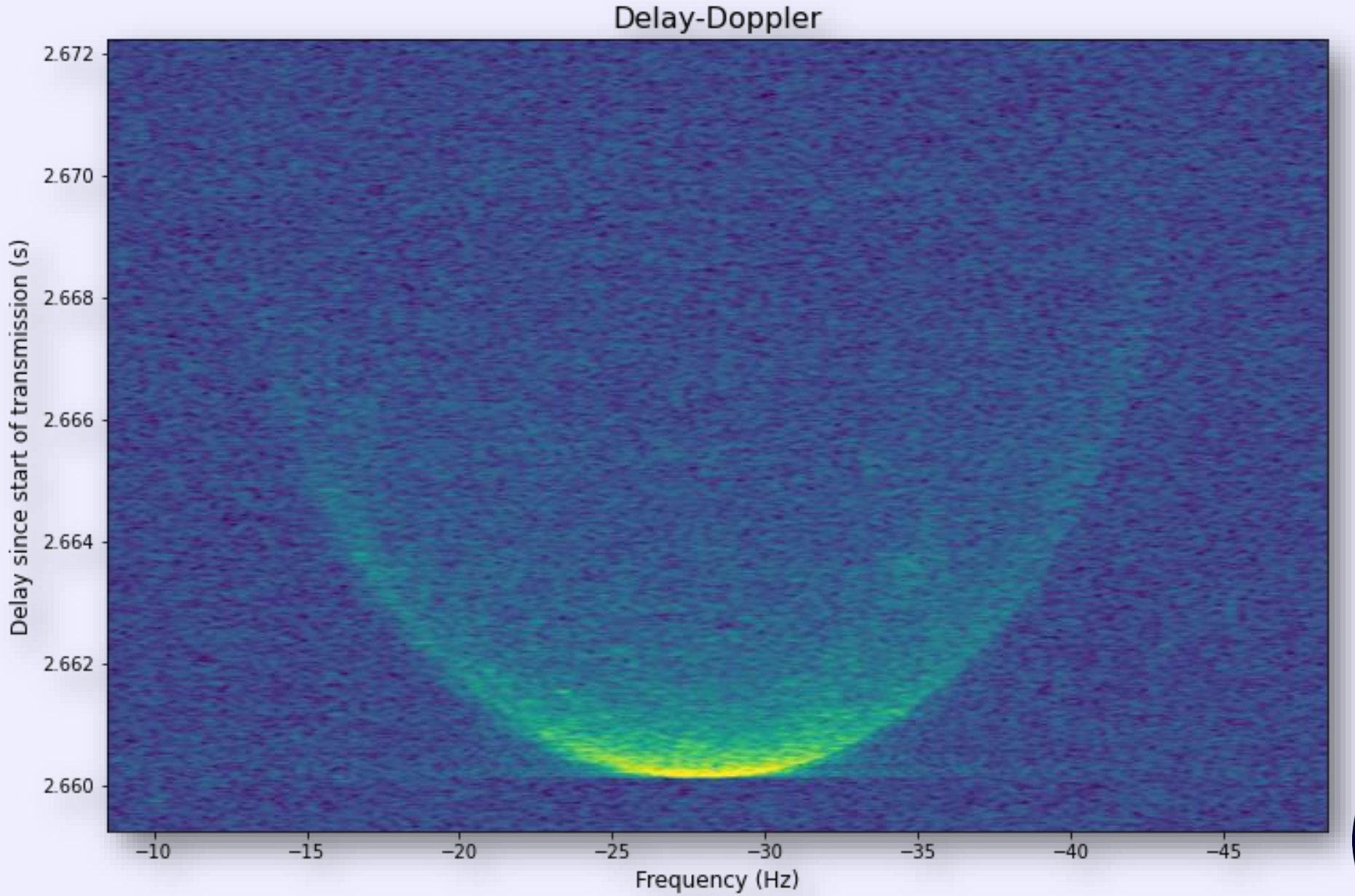


VRT (over ZMQ) applications

- Multiplex raw signal to different programs / computers
- Live pulsar waterfall; dspsr and psrchive in the background
- Data reduction 200km from Dwingeloo
- Replay VRT for development

Bonus: moon echos




Delay-Doppler
Delay since start of transmission (s)
2.672
2.670
2.668
2.666
2.664
2.662
2.660
−10
−15
−20
−25
−30
−35
−40
−45
Frequency (Hz)

Links

- www.camras.nl
- github.com/tftelkamp/vrt-iq-tools
- data.camras.nl/

- Mastodon:
  - @radiotelescoop@mastodon.nl
  - @pi9cam@botsin.space