



Photo:  
Albert van Duin

# DWINGELOO TRACKING



## **CAMRAS Operators**

Gerard Boons, Tammo Jan Dijkema, Harm Munk, Cees Bassa, Thomas Telkamp, John Nieuwerth, Herman Smit, Paul Schattenberg, Marc Wolf, Tjipke de Beer, Hans van der Meer, Jan van Muijlwijk, Gert Lammers

*Met dank aan alle CAMRAS-vrijwilligers!!*



1 juli 1955



17 april 1956



20 maart 2026



**20 maart 2026**



**Experimenten:**

**Pulsar timing**

**Waterstof (HVC)**

**OH**

**VLBI**

**EME (Moonbounce)**

**Radar Astronomie**

**EVE (Venus bounce)**

**Satellite bounce**

**Satellite tracking (LEO)**

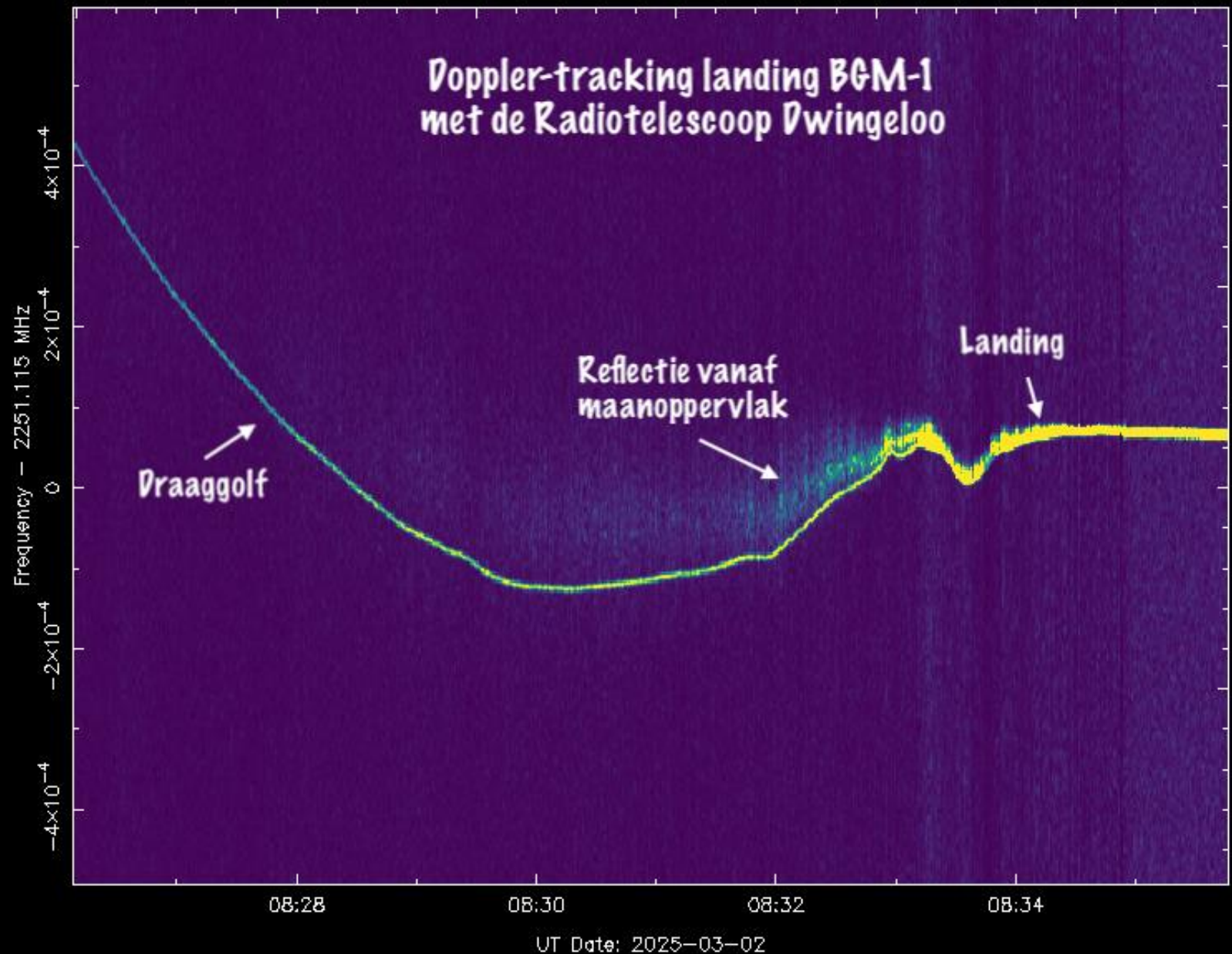
**Deep space (Voyager 1)**

**Maanmissies**

**...**

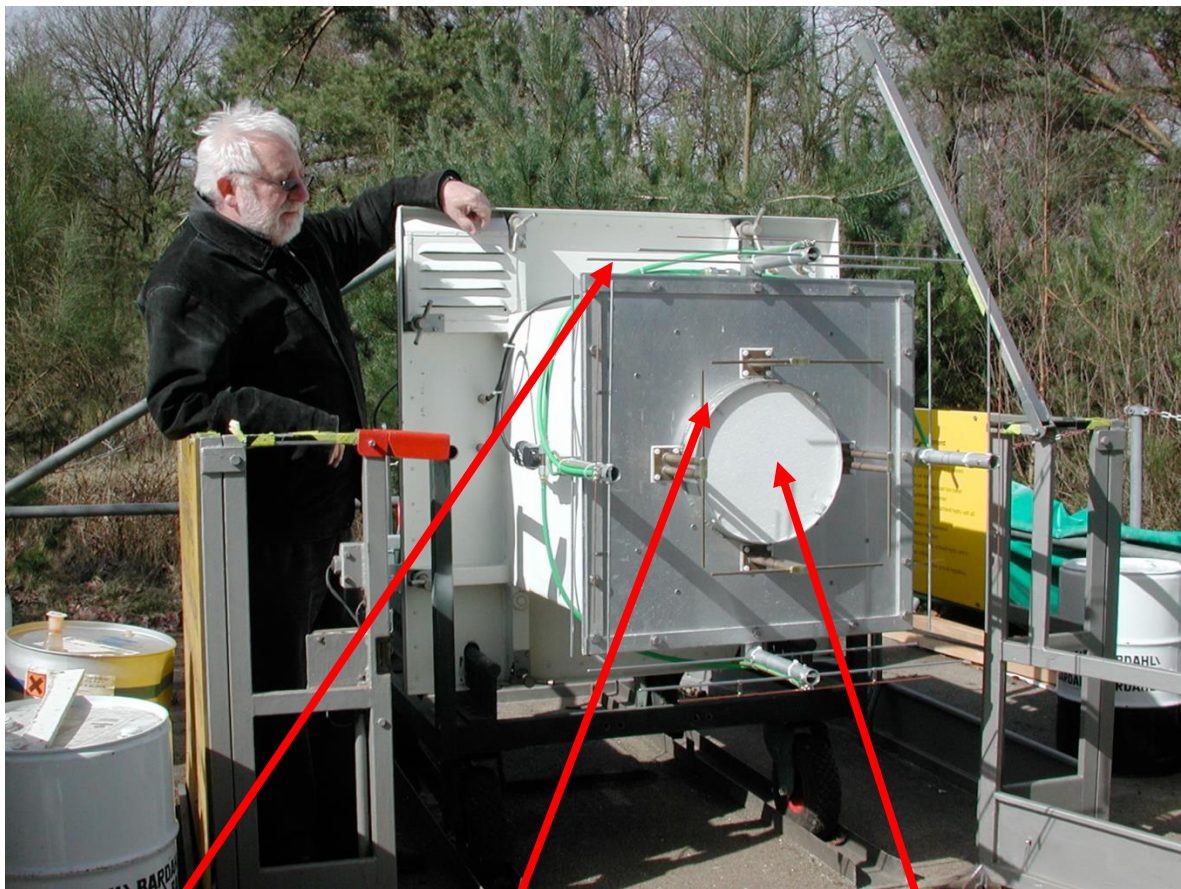
# Maanmissies gevolgd vanuit Dwingeloo

- 2018 🇨🇳 DSLWP-B 📡
- 2019 🇮🇱 Beresheet ✨
- 2019 🇮🇳 Chandrayaan 2 ✨
- 2022 🇺🇸 Artemis I 📡
- 2024 🇯🇵 SLIM 🛸
- 2024 🇺🇸 IM-1 🛸
- 2025 🇺🇸 BGM-1 🛸
- 2025 🇺🇸 IM-2 🛸
- 2025 🇯🇵 Hakuto-R ✨





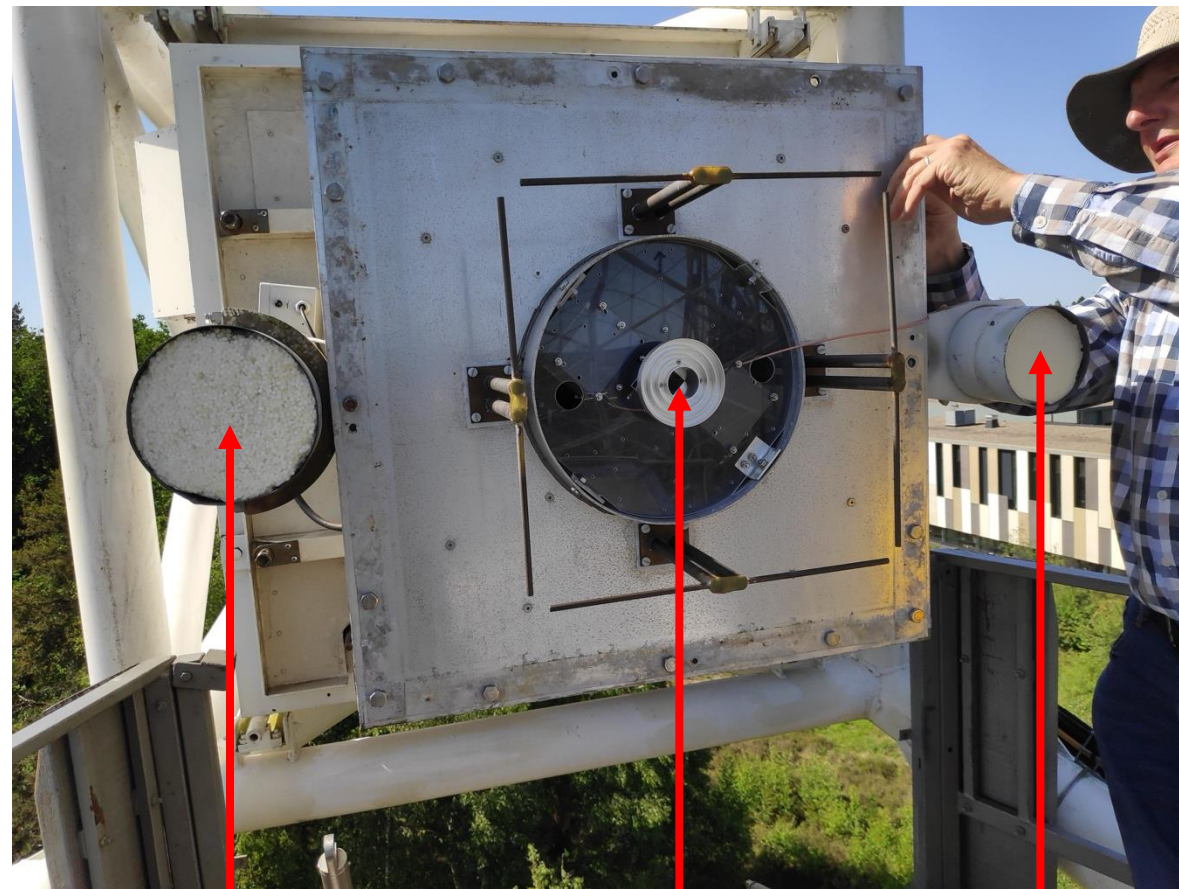




2m

70cm

23cm  
(21 cm)



13cm  
(2,1GHz)

3,5cm  
(8,4GHz)

9cm

# Artemis 1

## 2022



Volunteers Worldwide to Track Lunar Journey of NASA's Artemis I Mission

Working in Tandem: NASA's Networks Empower Artemis I

NASA Mirrors on ESA Pathfinder to Empower Space Geodesy

NASA Mirrors on ESA Pathfinder to Enhance Lunar Navigation

24. Deep Space Network - Follow the Sun | NASA's The Invisible Network Podcast

23. Deep Space Network - Origins | NASA's The Invisible Network Podcast

Season Five of "The Invisible Network" Podcast Explores NASA's Deep Space Network

### Participants:

#### Government Space Agencies

- Canadian Space Agency, Canada
- Centre National d'Etudes Spatiales (CNES), France
- German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt), Germany
- Korea Aerospace Research Institute (KARI), Republic of Korea
- National Space Centre, Efordstown Earthstation, Ireland

#### Commercial Companies

- Clearbox Systems Pty Ltd., Australia
- Goonhilly Earth Station Ltd., United Kingdom
- Intuitive Machines, USA
- Kongsberg Satellite Services (U.S. office), USA
- Leaf Space LLC, USA
- Swedish Space Corporation (U.S. office), USA
- Telespazio, Italy
- Vambrace Inc., USA
- Viasat, USA

#### Non-profit

- CAMRAS, Netherlands

#### Academic Institutions

- Space Systems Design Laboratory, Georgia Tech Research Institute, USA

#### Private Citizens

- Scott Chapman, USA
- Scott Tilley, Canada

# Artemis 1

2022

1		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	
2	Wednesday, 16 November 2022										j	j	j	j																		
3	Thursday, 17 November 2022				n	n	n	n	n	n	j	j	j	j	j	j																
4	Friday, 18 November 2022				n	n	n	n	n	n	j	j	j	j	j	n																
5	Saturday, 19 November 2022				n	n	n	n	n	n	j	j	j	j	j	j																
6	Sunday, 20 November 2022					n	n	n	n	n	n	j	j	j	j	j																
7	Monday, 21 November 2022					n	n	n	n	n	j	j	j	j	j	j																
8	Tuesday, 22 November 2022						n	j	j	j	j	j	j	j	j	j	j															
9	Wednesday, 23 November 2022									n	n	j	j	j	j	j	j															
10	Thursday, 24 November 2022										j	j	j	j	j	j	j															
11	Friday, 25 November 2022											j	j	j	j	j	j	j														
12	Saturday, 26 November 2022												j	j	j	j	j	j	j													
13	Sunday, 27 November 2022													j	j	j	j	j	j	j												
14	Monday, 28 November 2022														j	j	j	j	j	j	j											
15	Tuesday, 29 November 2022															j	j	j	j	j	j	j	j	j	j							
16	Wednesday, 30 November 2022																j	j	j	j	j	j	j	j	j							
17	Thursday, 1 December 2022																	j	j	j	j	j	j	j	j	j						
18	Friday, 2 December 2022																		j	j	j	j	j	j	j	j	j	n				
19	Saturday, 3 December 2022	j																		j	j	j	j	j	j	j	j	n	n	n		
20	Sunday, 4 December 2022	j	j																		j	j	j	j	j	j	j	n	n	n	n	n
21	Monday, 5 December 2022	j	j	j																		j	j	j	j	j	j	n	n	n	n	n
22	Tuesday, 6 December 2022	j	j	j	j																		j	j	j	j	j	n	n	n	n	n
23	Wednesday, 7 December 2022	j	j	j	j																			j	j	j	j	n	n	n	n	n
24	Thursday, 8 December 2022	j	j	j	j																				j	n	n	n	n	n		
25	Friday, 9 December 2022	j	j	j	j																					j	n	n	n			
26	Saturday, 10 December 2022	j	j	j																							j	n	n	n		

Artemis 1 crew

NASA



1 april 2026

NASA / Bill Ingalls





NASA



2 MIN READ

# NASA Seeks Volunteers to Track Artemis II Mission

On the 19th day of the Artemis I mission, Dec. 4, 2022, a camera mounted on the Orion spacecraft captured the Moon just in frame.

Credits: NASA



**Katrina Lee**



**Katherine Schauer**

AUG 27, 2025

ARTICLE



NASA seeks volunteers to passively track the Artemis II Orion spacecraft as the crewed mission travels to the Moon and back to Earth.

The Artemis II test flight, a launch of the agency's SLS (Space Launch System) rocket and Orion spacecraft, will send NASA astronauts Reid Wiseman, Victor Glover, and Christina Koch, along with CSA (Canadian Space Agency) astronaut Jeremy Hansen, on an approximately 10-day mission around the Moon.

The mission, targeted for no later than April 2026, will rely on NASA's Near Space Network and Deep Space Network for primary communications and tracking support throughout its launch, orbit, and reentry. However, with a growing focus on commercialization, NASA wants to further understand industry's tracking capabilities.

This collaboration opportunity builds upon a [previous request](#) released by NASA's SCA (Space Communication and Navigation) Program during the Artemis I mission, where ten volunteers

4 MIN READ

# NASA Selects Participants to Track Artemis II Mission

A visual representation of NASA's Artemis I mission.

Credits: NASA



Katrina Lee

JAN 23, 2026

ARTICLE



## Participants List:

### Government:

- Canadian Space Agency (CSA), Canada
- The German Aerospace Center (DLR), Germany

### Commercial:

- Goonhilly Earth Station Ltd, United Kingdom
- GovSmart, Charlottesville, Virginia
- Integrasys + University of Seville, Spain
- Intuitive Machines, Houston
- Kongsberg Satellite Services, Norway
- Raven Defense Corporation, Albuquerque, New Mexico
- Reca Space Agency + University of Douala, Cameroon
- Rincon Research Corporation & the University of Arizona, Tucson
- Sky Perfect JSAT, Japan
- Space Operations New Zealand Limited, New Zealand
- Telespazio, Italy
- ViaSat, Carlsbad, California
- Von Storch Engineering, Netherlands

### Individual:

- Chris Swier, South Dakota
- Dan Slater, California
- Loretta A Smalls, California
- Scott Tilley, Canada

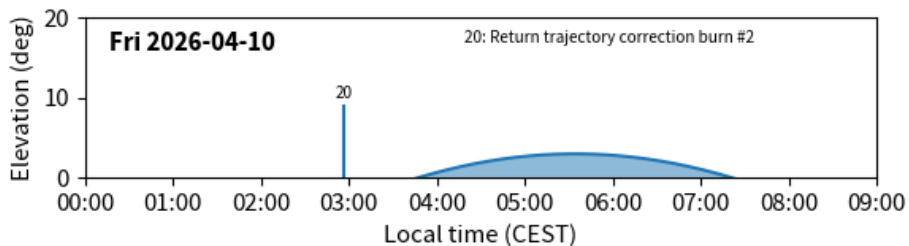
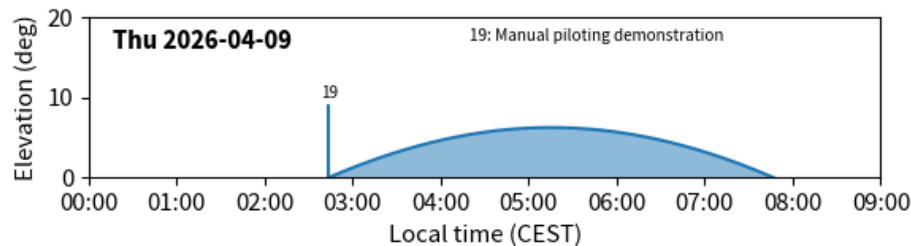
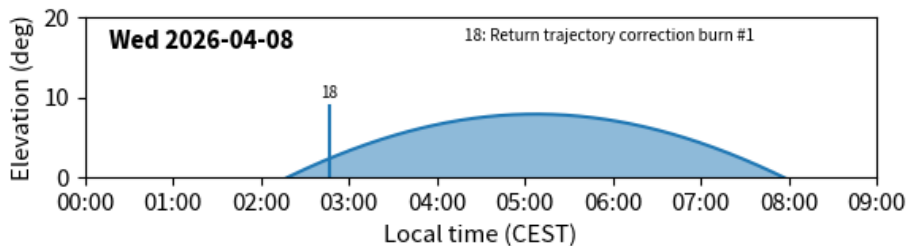
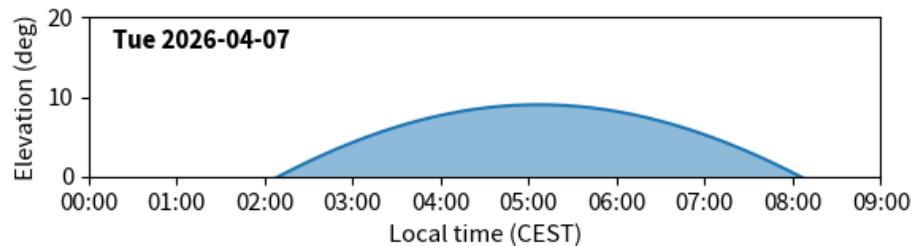
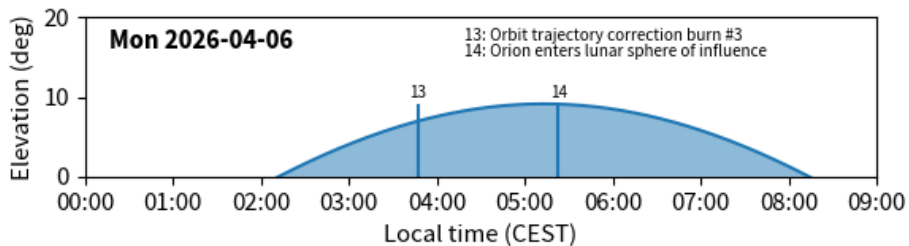
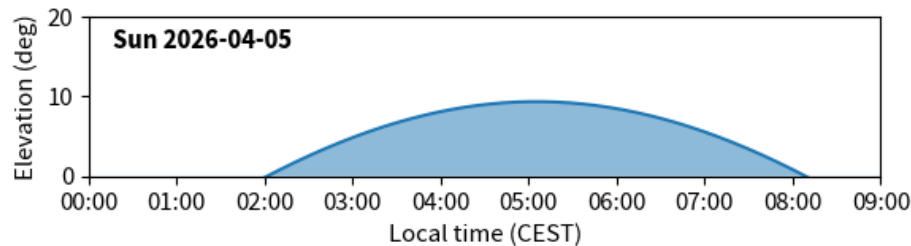
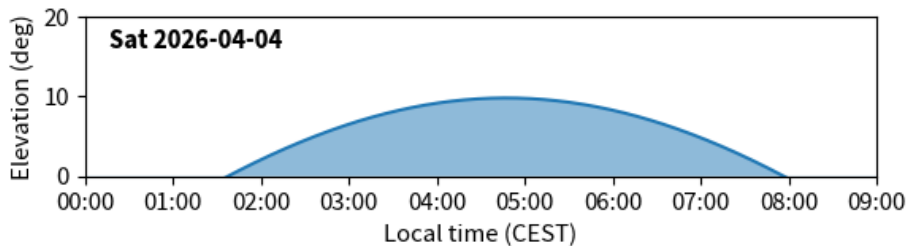
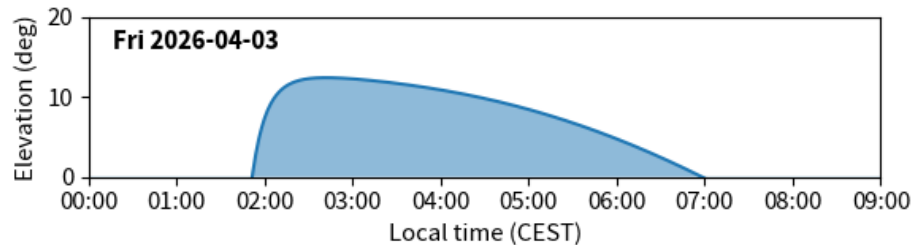
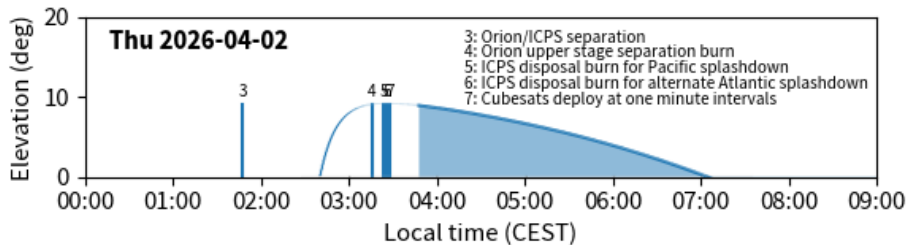
### Academia:

- American University, Washington
- Awara Space Center + Fukui University of Technology, Japan
- Morehead State University, Morehead, Kentucky
- Pisgah Astronomical Research Institute, Rosman, North Carolina
- University of California Berkeley, Space Sciences Laboratory, California
- University of New Brunswick, ECE, Canada
- University of Pittsburgh, ECE, Pittsburgh
- University of Zurich – Physics Department, Switzerland

### Non-Profit & Amateur Radio Organizations:

- AMSAT Argentina, Argentina
- AMSAT Deutschland, Germany
- Amateur Radio Exploration Ground Station Consortium, Towson, Maryland
- CAMRAS, Netherlands ←
- Deep Space Exploration Society, Kiowa County, Colorado
- Neu Gollm Ground Station, Germany
- Observation Radio Pleumeur-bodou, France

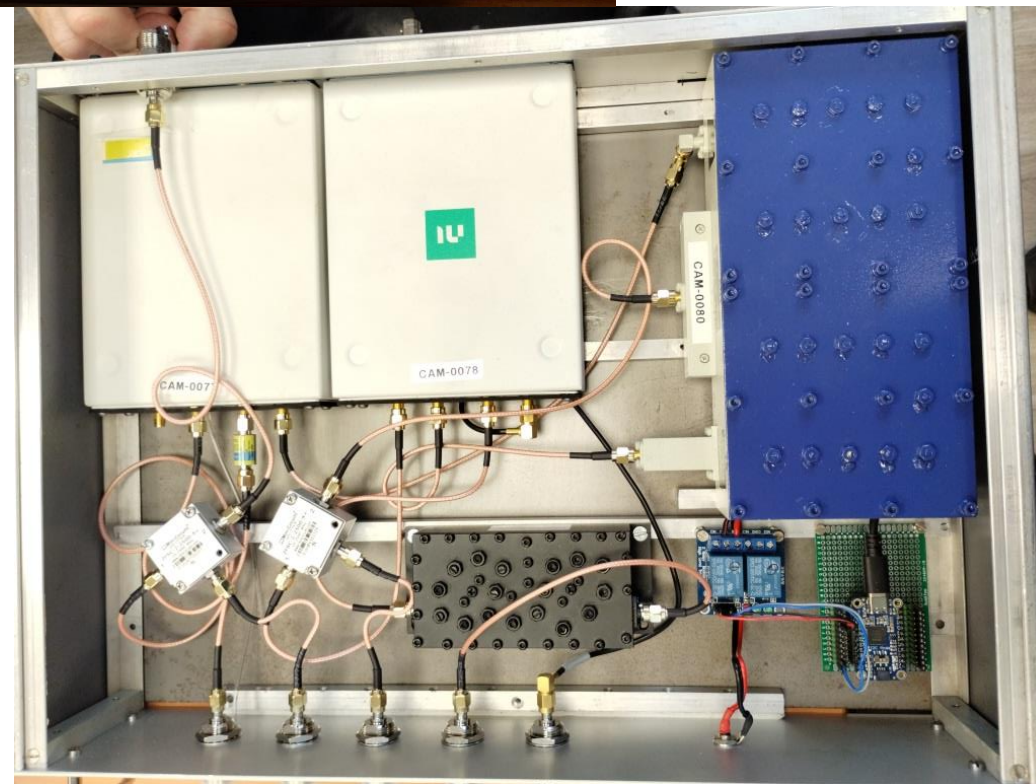
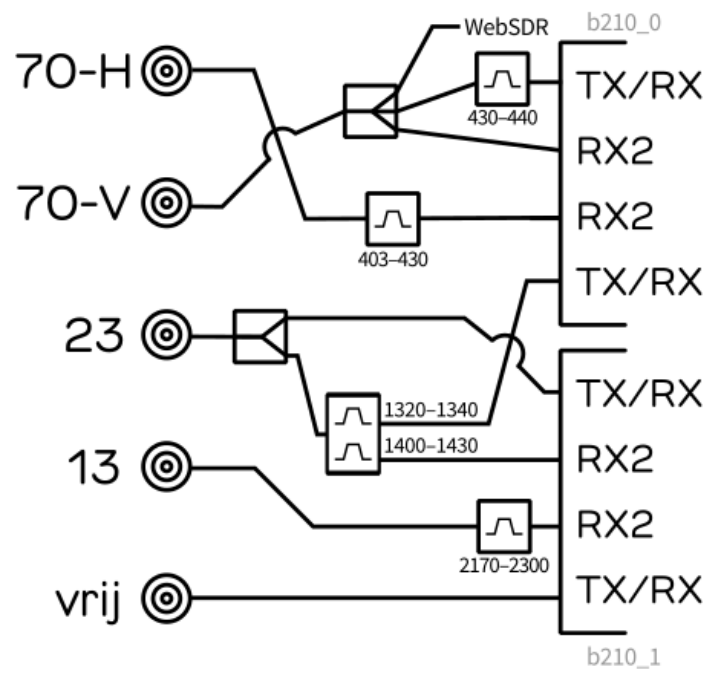
# Dwingeloo visibility of Artemis II for launch 2026-04-01 22:24 UTC



02 Apr 2026 03:22

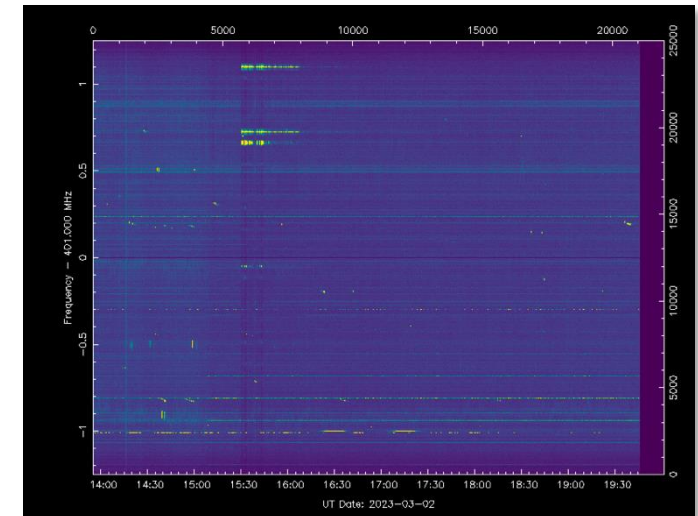
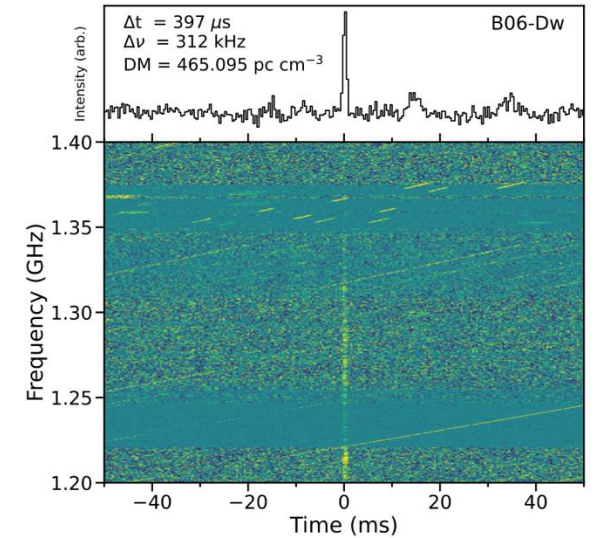
Observed from Dwingeloo



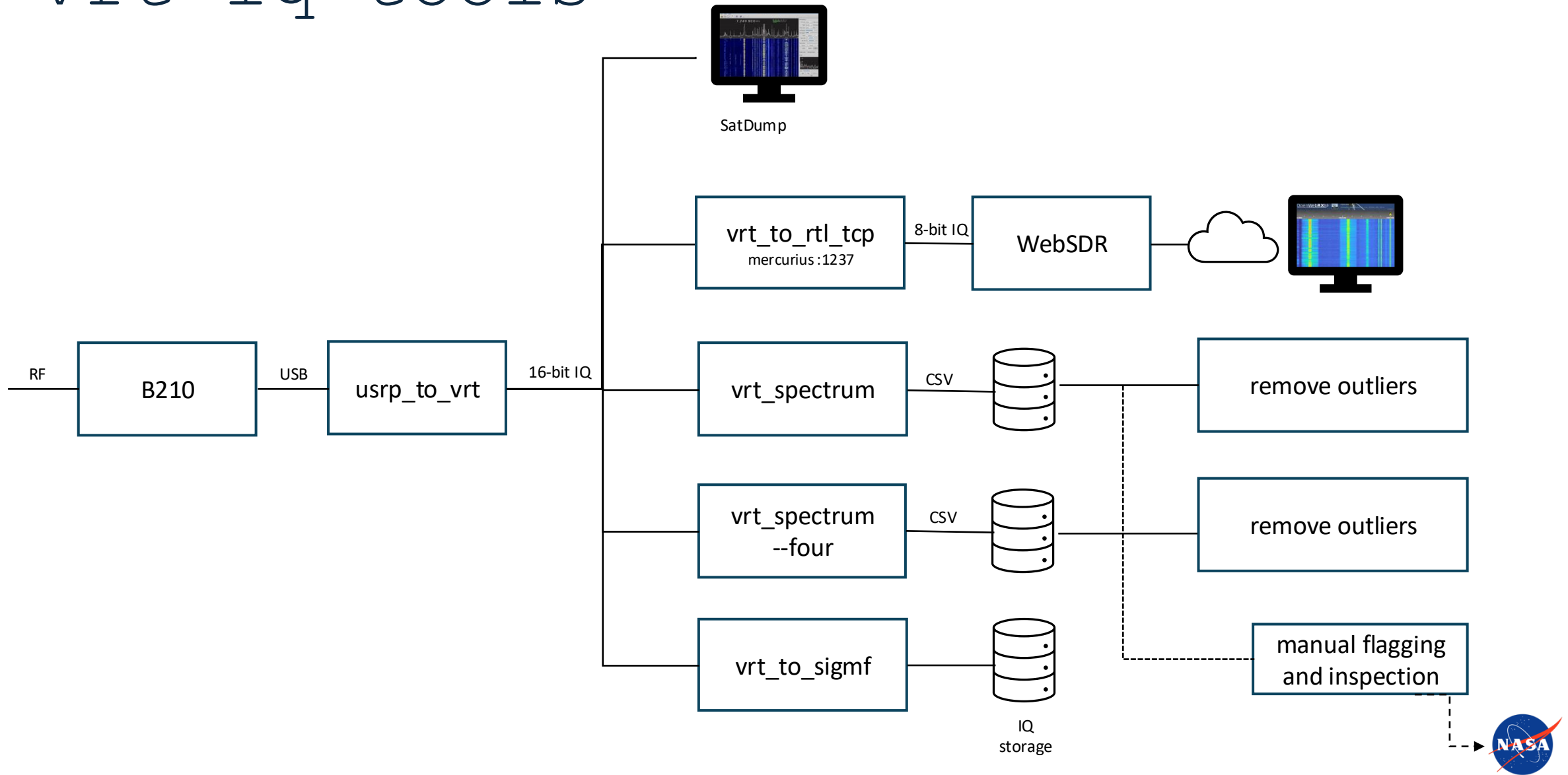


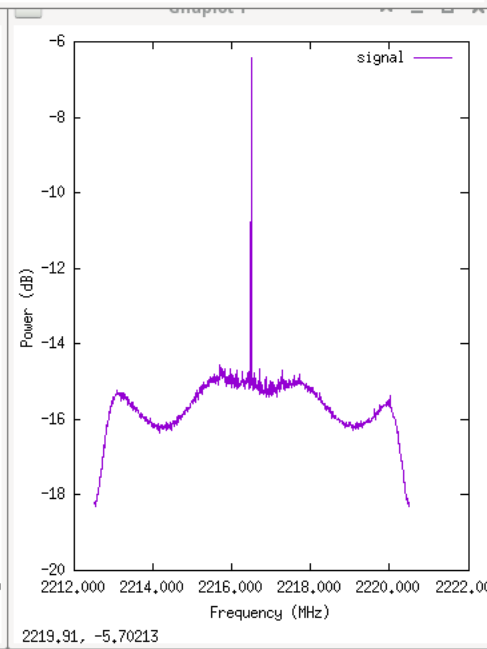
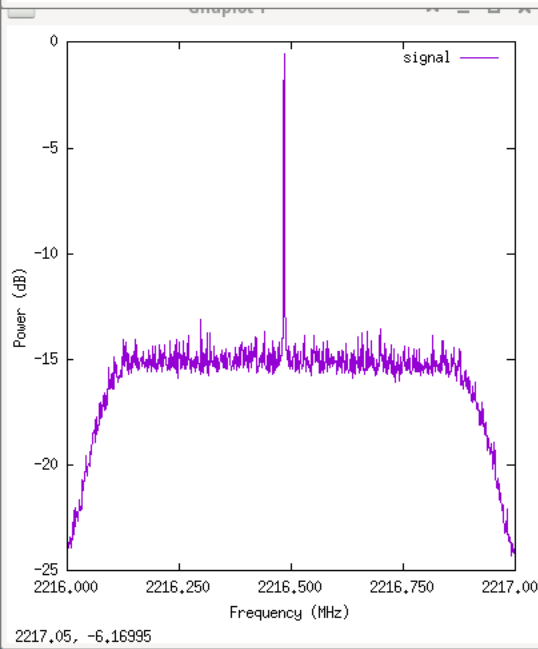
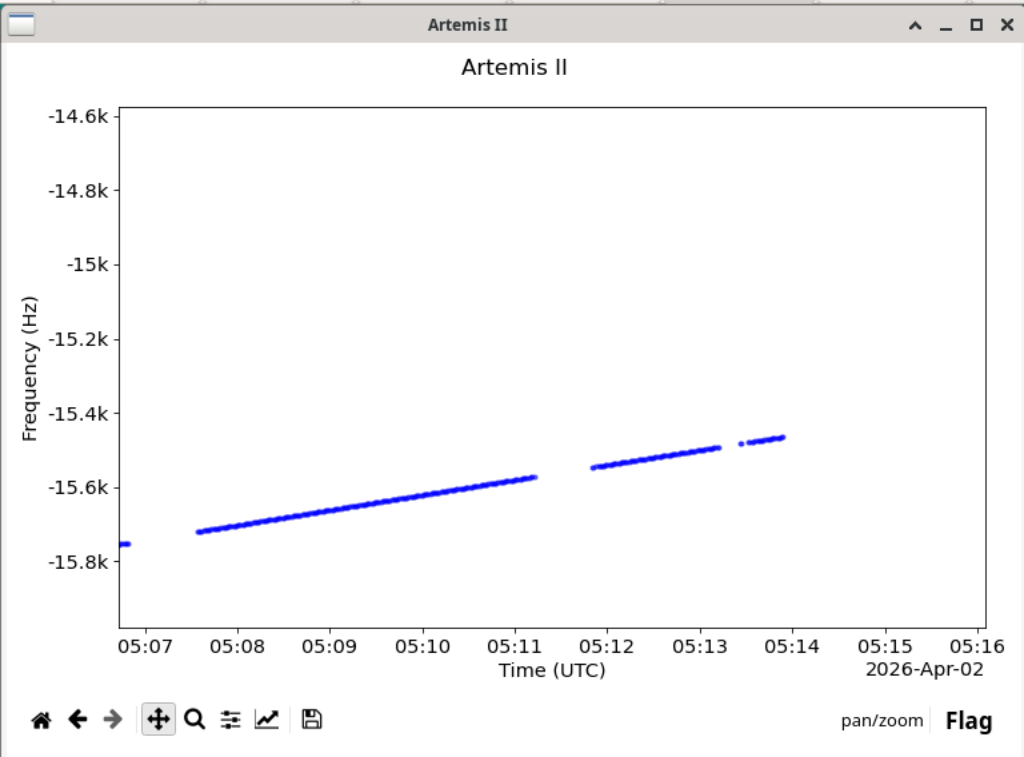
# vrt-iq-tools

- `vrt_to_filterbank`: pulsar, FRB, and SETI
- `vrt_pulsar`: live dedispersion and folding
- `vrt_to_dada`: pulsar processing
- `vrt_to_sigmf`: SigMF
- `vrt_rffft`: STRF, Cees Bassa
- `vrt_to_gnuradio`: GNU Radio
- `vrt_tuner`: extract sub-band
- `vrt_channelizer*`: extract all sub-bands
- `vrt_to_void`: nothing
- `vrt_correlate`: correlator for interferometry
- `vrt_forwarder`: local fanout
- `control_vrt`: SDR control
- `play_vrt`: transit SigMF  
\* also GPU version
- and more...



# vrt-iq-tools





SDR++ v1.2.1 (Built at 10:56:41, Mar 2 2025)

002.21

Source: VRTZMQ

Host: 127.0.0.1

Instance: 0

Channel: 0

Port: 53100

Use Port:

IQ Correction:

Invert IQ:

Offset mode: None

Offset: 0.000000

Decimation: None

Radio:

Recorder:

Sinks:

Frequency Manager:

VFO Color:

Display:

Show Waterfall:

Full Waterfall Update:

Lock Menu Order:

FFT Hold: 60

FFT Smoothing: 25

SNR Smoothing: 20

High-DPI Scaling: 100%

FFT Framerate: 8

FFT Size: 131072

FFT Window: Nuttall

Color Map: GQRX

Color map Author: csete

Band Plan:

Theme:

Module Manager:

Rigctl Server:

Debug:

Artemis II

tracking

usrp\_artemis

fftmax\_four

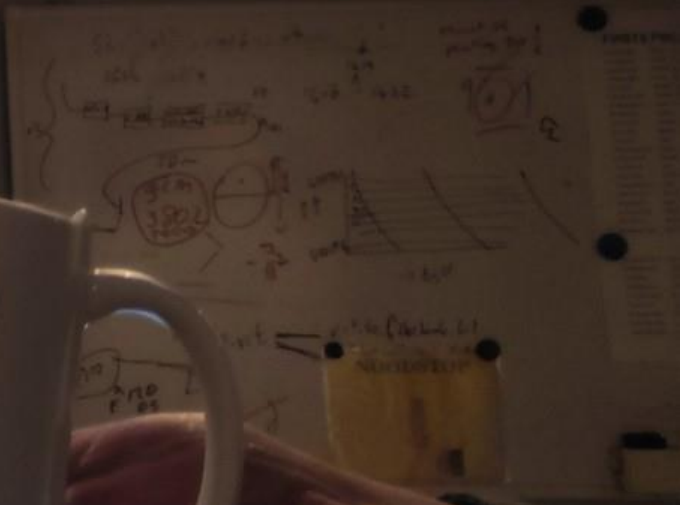
fftmax

vrt\_to\_gnuradio

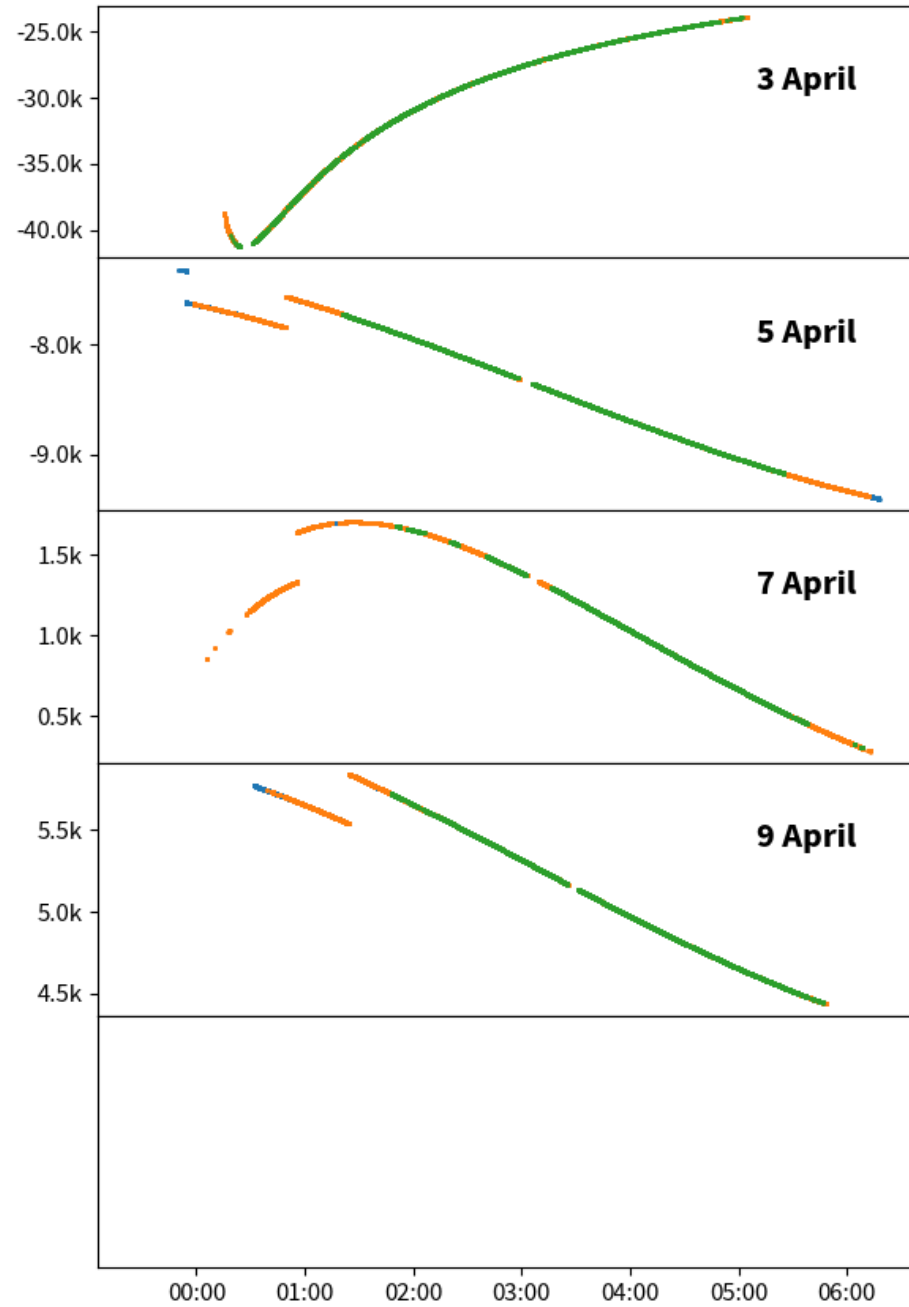
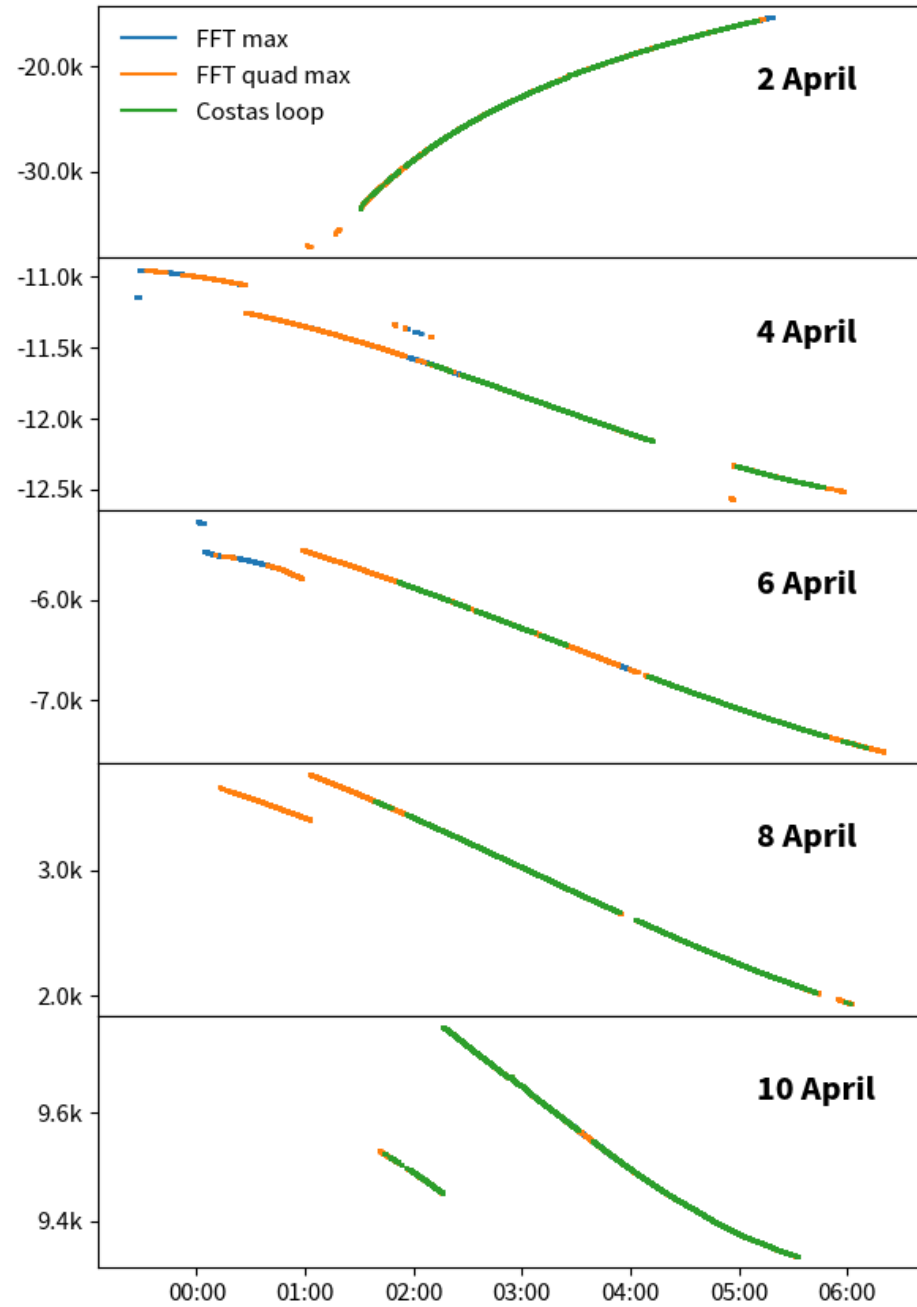
vrt\_tuner

vrt\_to\_rtl\_tcp

vrt\_to\_sigmf



# Doppler data collected with Dwingeloo telescope



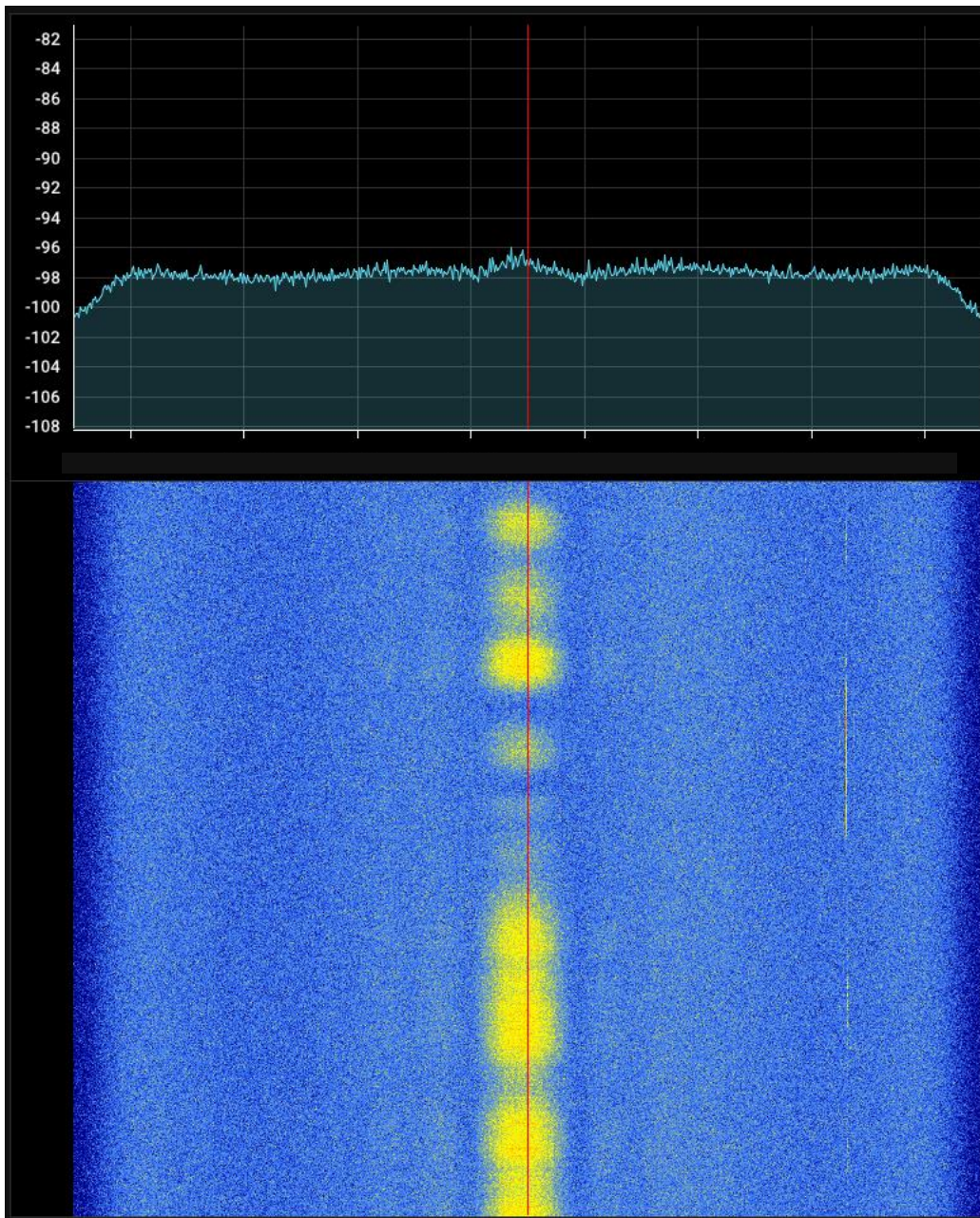
Singaal: GHz  
Doppler: kHz  
Offset: Hz  
Accuracy: mHz

**40 uur data  
gedeeld met  
NASA**

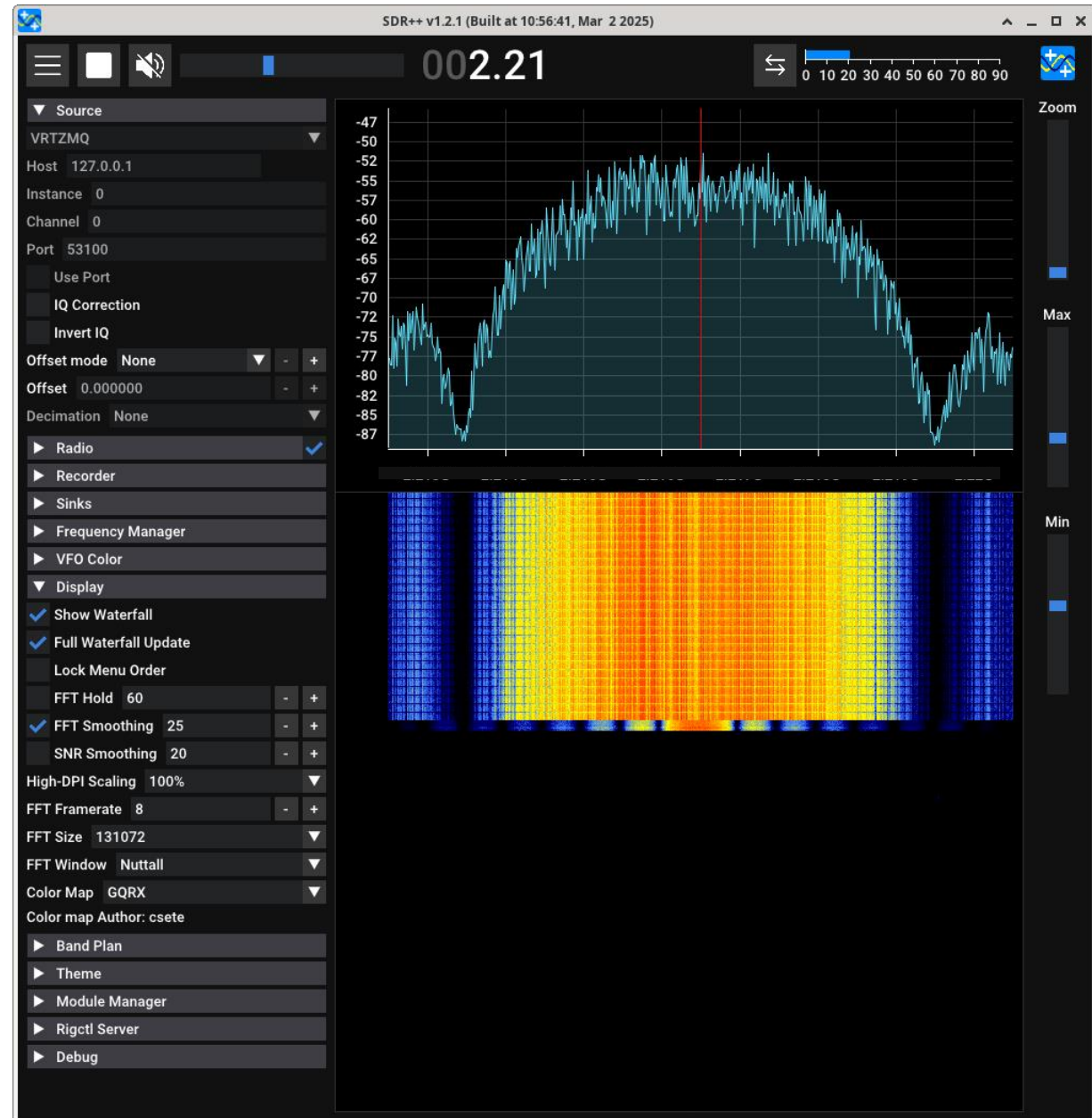
**DWINGELOO  
TRACKING**

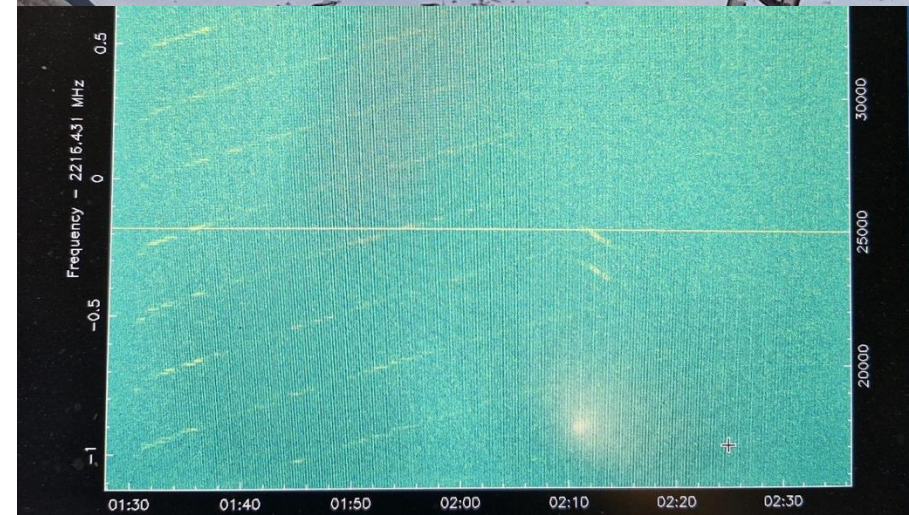
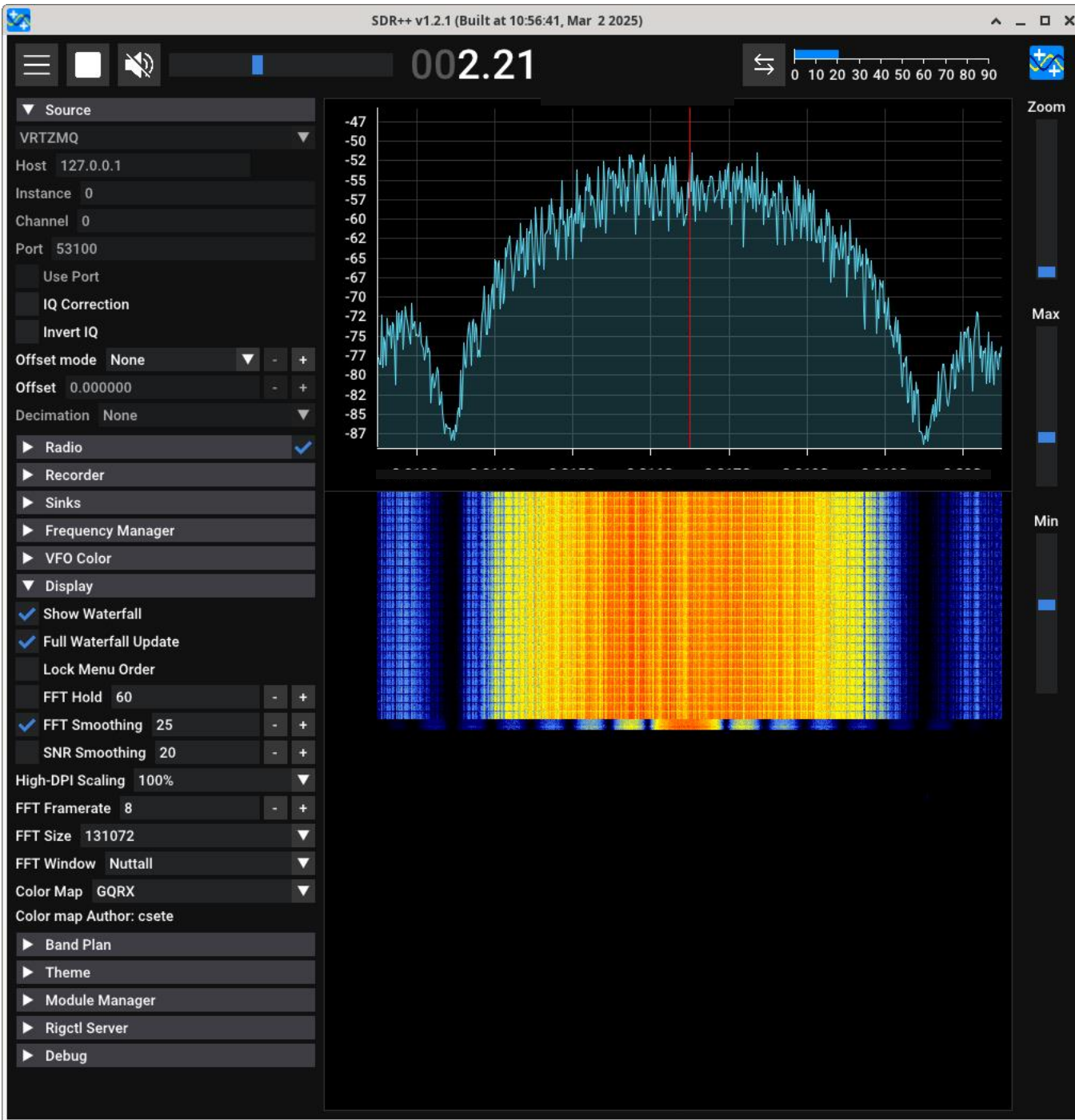


2 april 01:02 UTC: eerste signaal

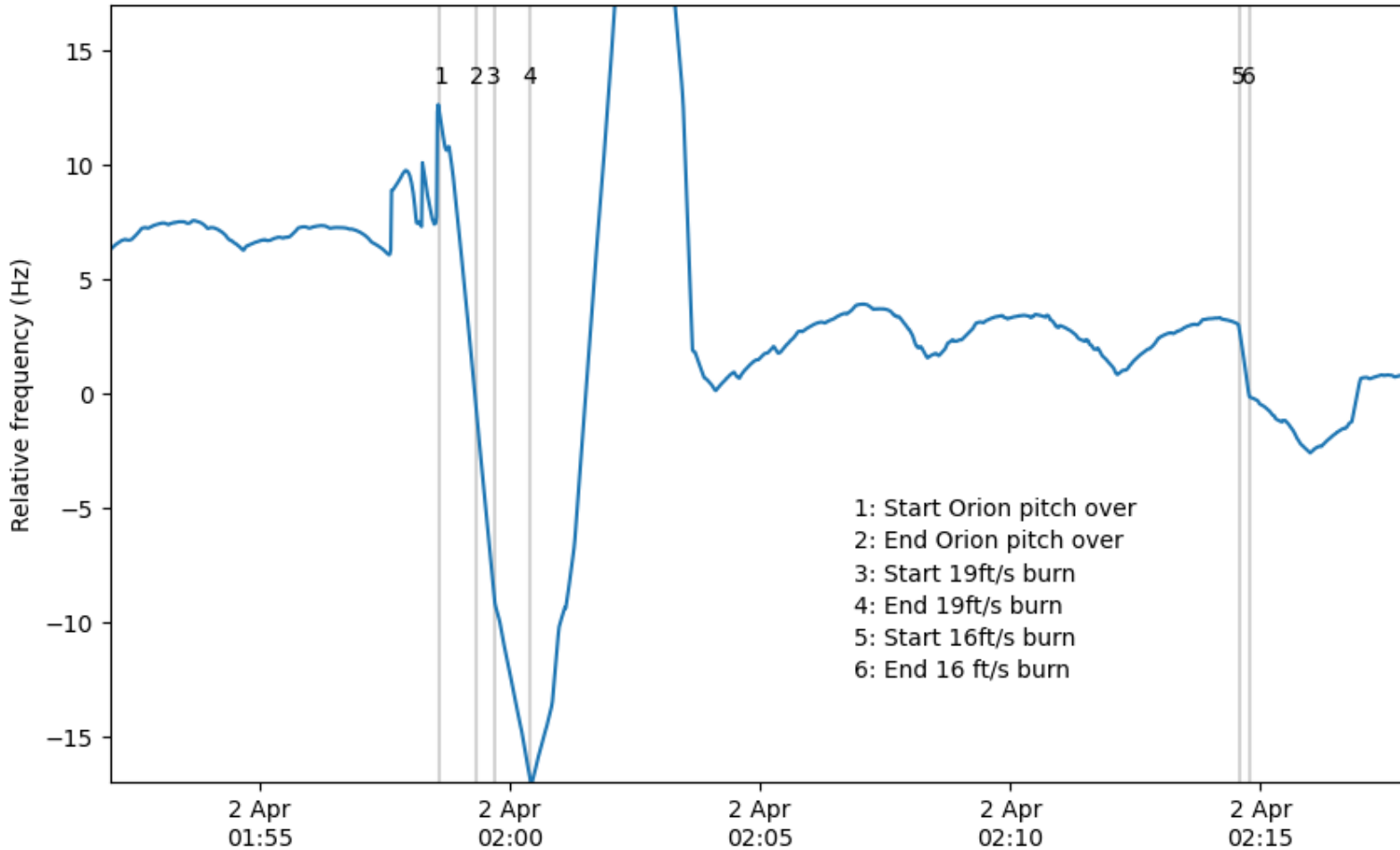


2 april 01:30 UTC: signaalsterkte gaat omhoog

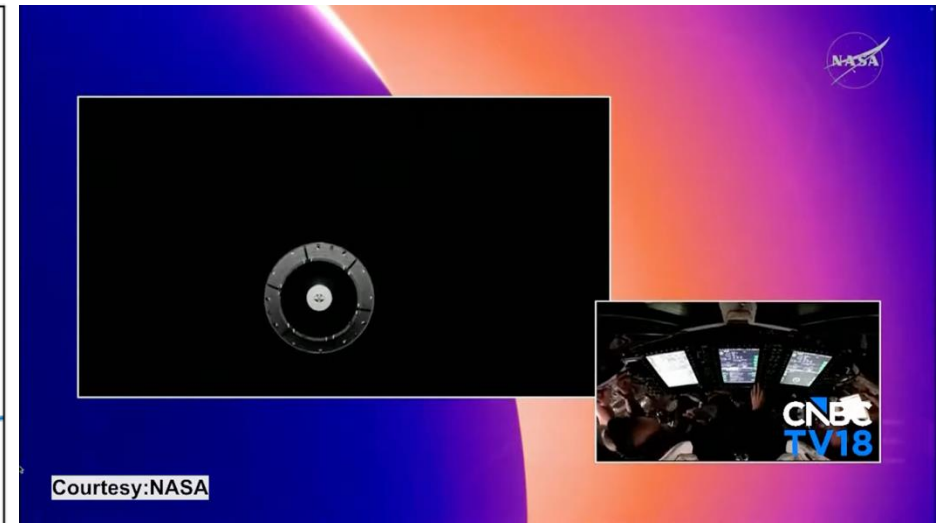




# Proximity operations gezien in Doppler



Data reduction: Cees Bassa / Tammo Jan Dijkema

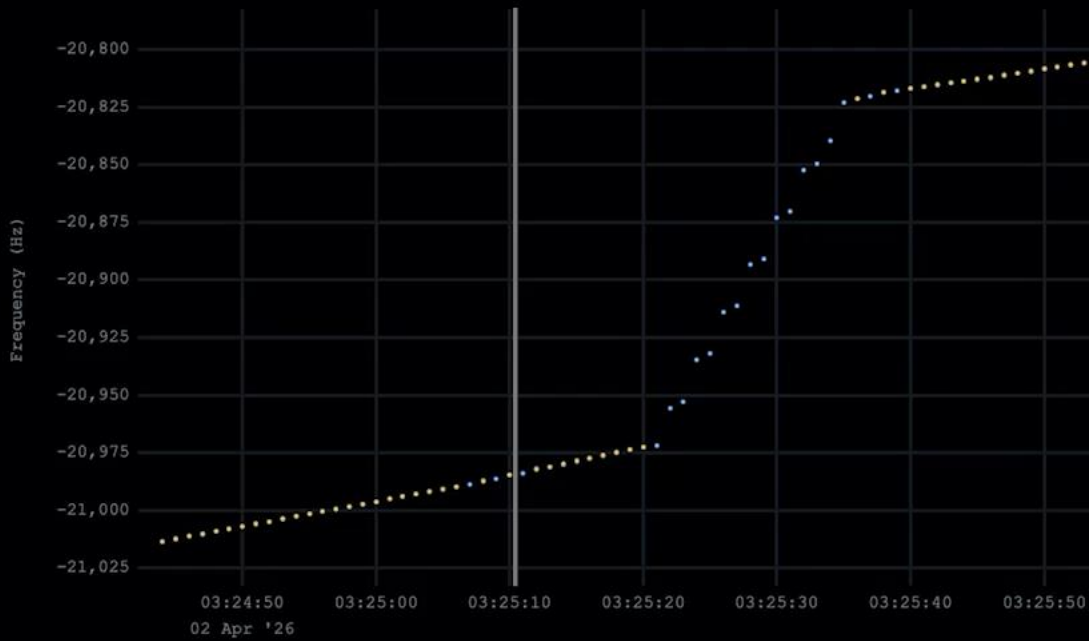
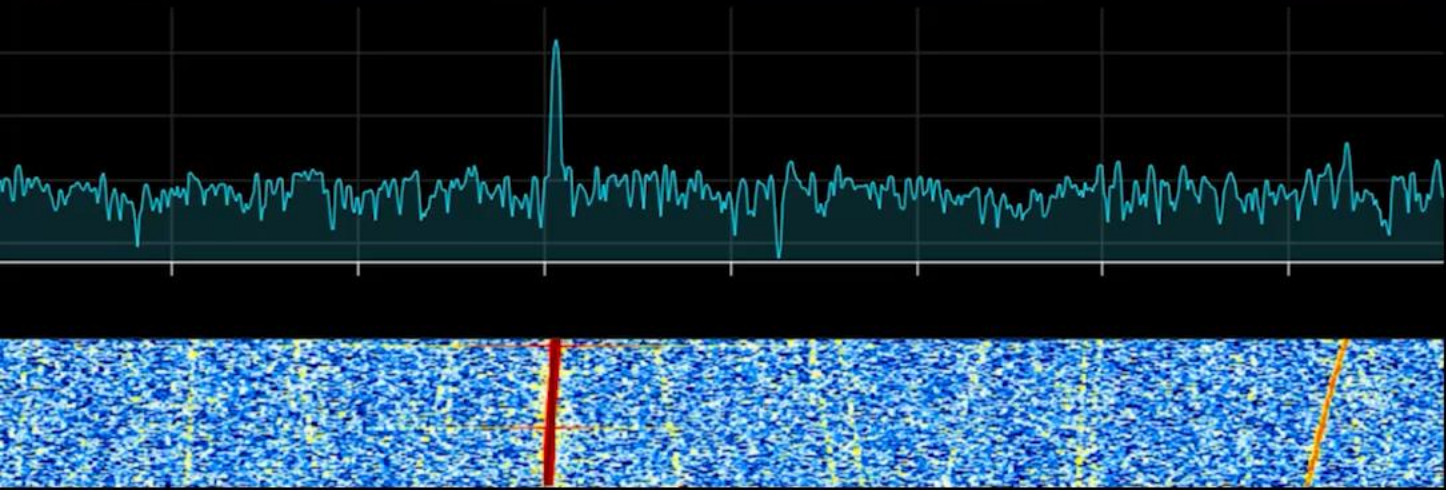


## DWINGELOO TRACKING





Courtesy:NASA



## → HOW NOT TO LOSE A SPACECRAFT

### Delta-DOR

ESA's ultra-precise deep-space navigation technique tells us where spacecraft are to within a few hundred metres even at a distance of 100 000 000 km. Navigating a spacecraft around our Solar System requires knowing how far it is, how fast it is travelling and in what direction.

#### HOW FAR IS IT?

Using a single ground station on Earth, the **distance** to a spacecraft in deep space can be determined from the time it takes a radio signal to travel from the spacecraft to the ground station antenna.



#### COMING OR GOING?

How quickly is a spacecraft moving along the 'line-of-sight', i.e. away from or towards Earth? We determine this from the frequency of the radio signal sent from the spacecraft, which changes depending on whether the craft is moving **toward us** (higher frequency) or **away from us** (lower frequency). This is called the **Doppler shift**.



#### LEFT OR RIGHT?

Now for the tricky bit! Is the spacecraft moving left or right in the sky? Two of ESA's three widely separated deep-space ground stations capture signals coming from the spacecraft, using the **difference** in their time of arrival to determine its 'perpendicular' or 'angular' position.



#### BRIGHTEST BEACONS!

Earth's atmosphere and the ground station electronics delay the spacecraft's signal, creating uncertainty in its location. To remove this uncertainty, two stations also receive signals from another radio source nearby in the sky, whose position is very precisely known – a **Quasar**. Subtracting the 'received' Quasar location from the received spacecraft measurement removes all delays common to both – giving the **Delta** in the name of this technique, dubbed '**Delta-Differential One-Way Ranging**'.



Earth's atmosphere

Doppler shift

→ direction of travel

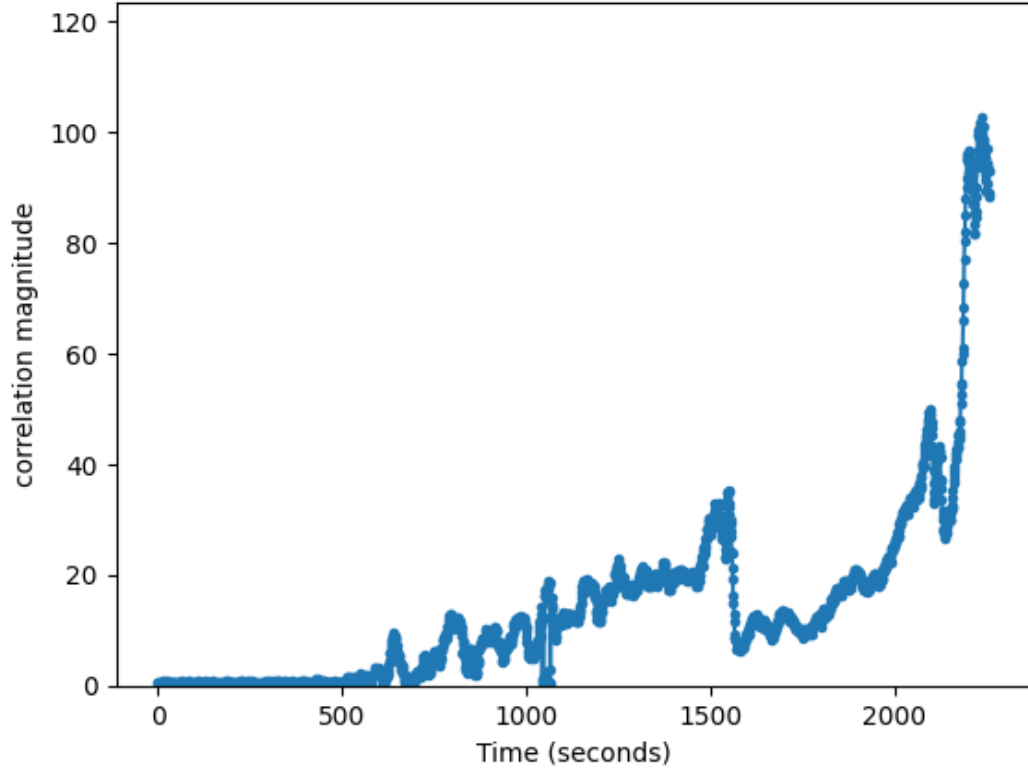
slightly longer path

→ direction of travel

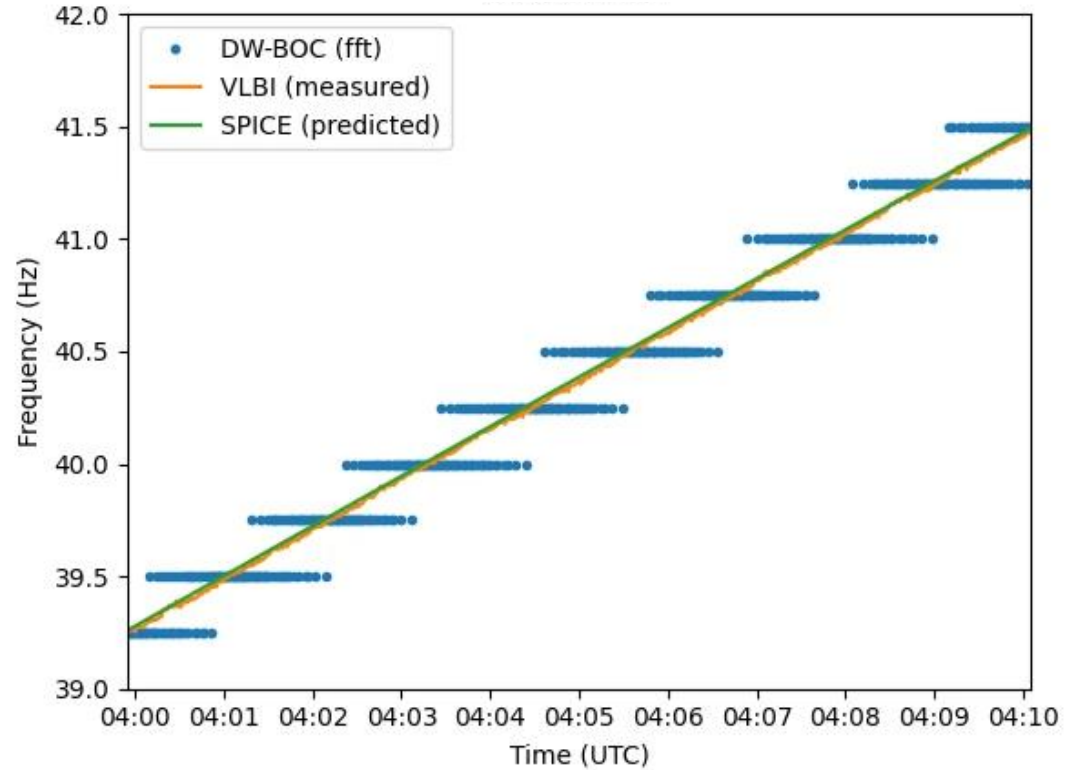
10°

Quasars are some of the brightest objects in our Universe; their colossal energy comes from matter falling into a black hole. They are very, very far away but their positions are known very accurately, so they serve as 'beacons' for this technique.

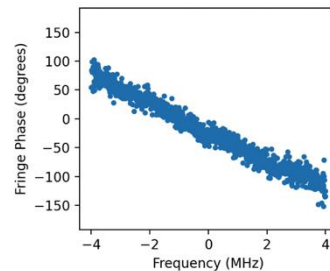
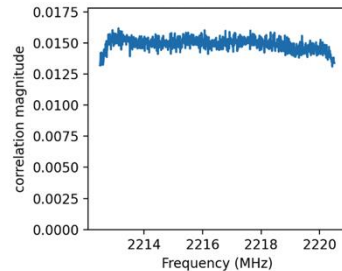
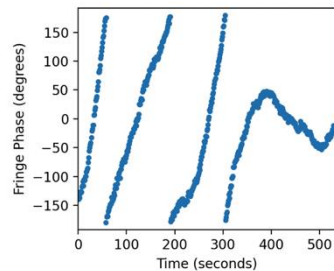
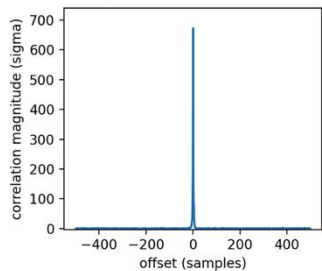
## Correlatie Dwingeloo – Bochum Artemis 2



## Doppler afgeleid uit Bochum – Dwingeloo



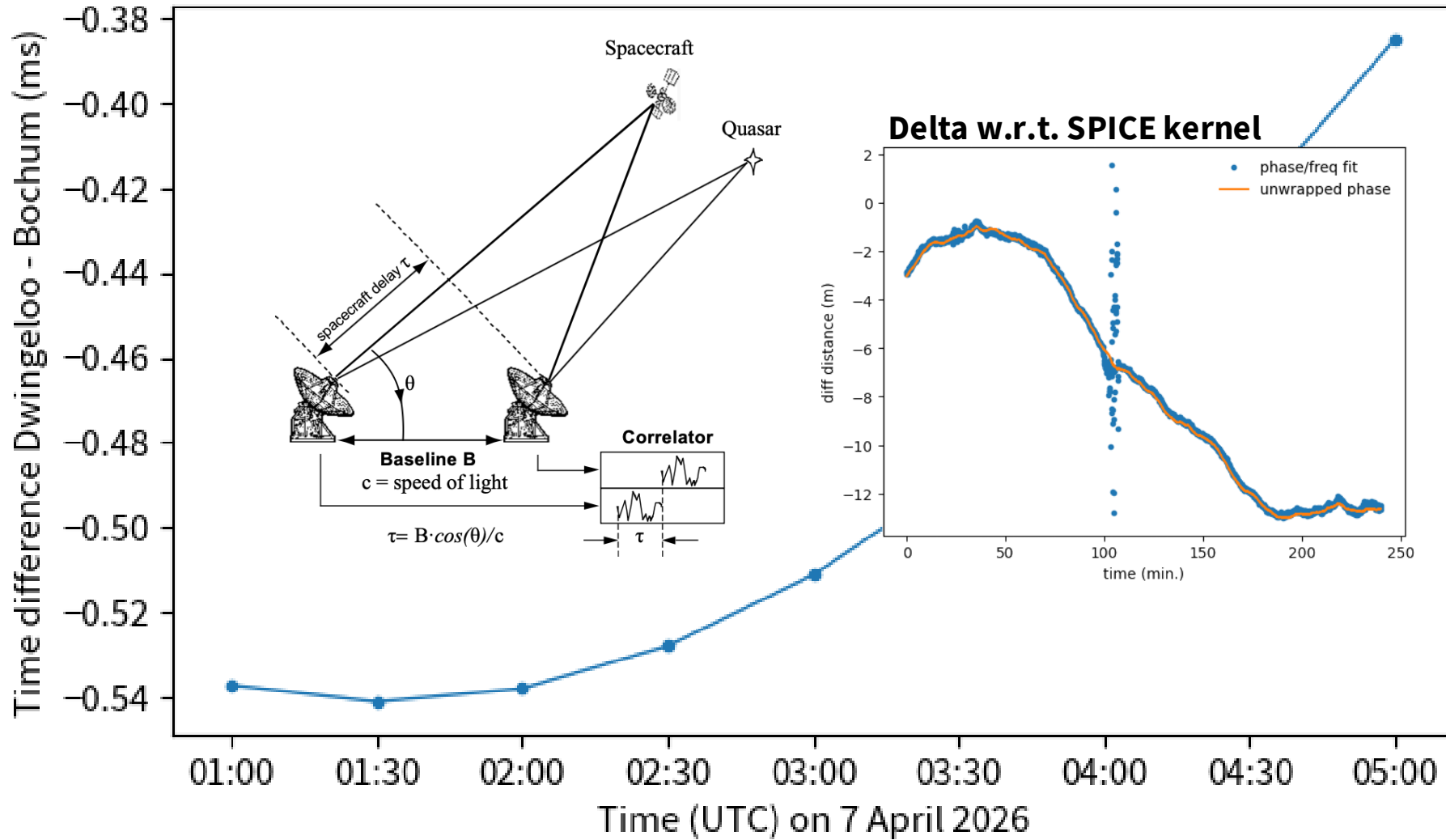
geloos  
@ 2.2GHz



Sternwarte Bochum  
20m @ 2.2GHz

Dwingeloo – Bochum VLBI on 3C273 @ 2.2GHz

# Delta-DOR Dwingeloo - Bochum



Dwingeloo  
25m @ 2.2GHz



Sternwarte Bochum  
20m @ 2.2GHz

CCSDS\_TDM\_VERS = 2.0

COMMENT CAMRAS Dwingeloo Radio Telescope Tracking

CREATION\_DATE = 2026-096T18:39:21

ORIGINATOR = CAMRAS

MESSAGE\_ID = CAMRAS\_Dwingeloo\_20260404

META\_START

TIME\_SYSTEM = UTC

START\_TIME = 2026-094T23:58:20:000006

STOP\_TIME = 2026-095T00:49:38:000006

PARTICIPANT\_1 = ORION

PARTICIPANT\_2 = DWINGELOO

PATH = 1,2

MODE = SEQUENTIAL

INTEGRATION\_INTERVAL = 1.0

INTEGRATION\_REF = MIDDLE

FREQ\_OFFSET = 0.0

DATA\_QUALITY = RAW

TURNAROUND\_NUMERATOR = 240

TURNAROUND\_DENOMINATOR = 221

META\_STOP

DATA\_START

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RECEIVE\_FREQ\_2 = 2026-094T23:58:21.500006 22: 1.000

RECEIVE\_FREQ\_2 = 2026-094T23:58:22.500006 22: 1.000

RECEIVE\_FREQ\_2 = 2026-094T23:58:23.500006 22: 1.750

RECEIVE\_FREQ\_2 = 2026-094T23:58:24.500006 22: 1.750

RECEIVE\_FREQ\_2 = 2026-094T23:58:25.500006 22: 1.750

RECEIVE\_FREQ\_2 = 2026-094T23:58:26.500006 22: 1.500

RECEIVE\_FREQ\_2 = 2026-094T23:58:27.500006 22: 1.750

RECEIVE\_FREQ\_2 = 2026-094T23:58:28.500006 22: 1.750

RECEIVE\_FREQ\_2 = 2026-094T23:58:29.500006 22: 1.500

RECEIVE\_FREQ\_2 = 2026-094T23:58:30.500006 22: 1.250

RECEIVE\_FREQ\_2 = 2026-094T23:58:31.500006 22: 1.250

RECEIVE\_FREQ\_2 = 2026-094T23:58:32.500006 22: 1.250

RECEIVE\_FREQ\_2 = 2026-094T23:58:33.500006 22: 1.250

# Data met NASA gedeeld



DWINGELOO  
TRACKING



CAMRAS - WebSDR — Mozilla Firefox

Dwingeloo Telescope Azimuth × CAMRAS - WebSDR MUTED × +

← → ↻ 🔒 🔗 websdr.camras.nl:8901 🔍 Search

⚙️ Most Visited 🌐 GRAVES CAMRAS - W... 🌐 Dourbes CAMRAS - W... 🌐 JOTA CAMRAS - WebS... 🌐 Websdr 🌟 Ham Radio Maidenh... >> 📁 Other Bookmarks

Band:  Artemis  70cm sat  70cm EME  70cm H  70cm L  2m  graves  aero  4m  6m  lofar  jove

Volume:   mute

This WebSDR is currently being used by 38 user(s) simultaneously:  compact view

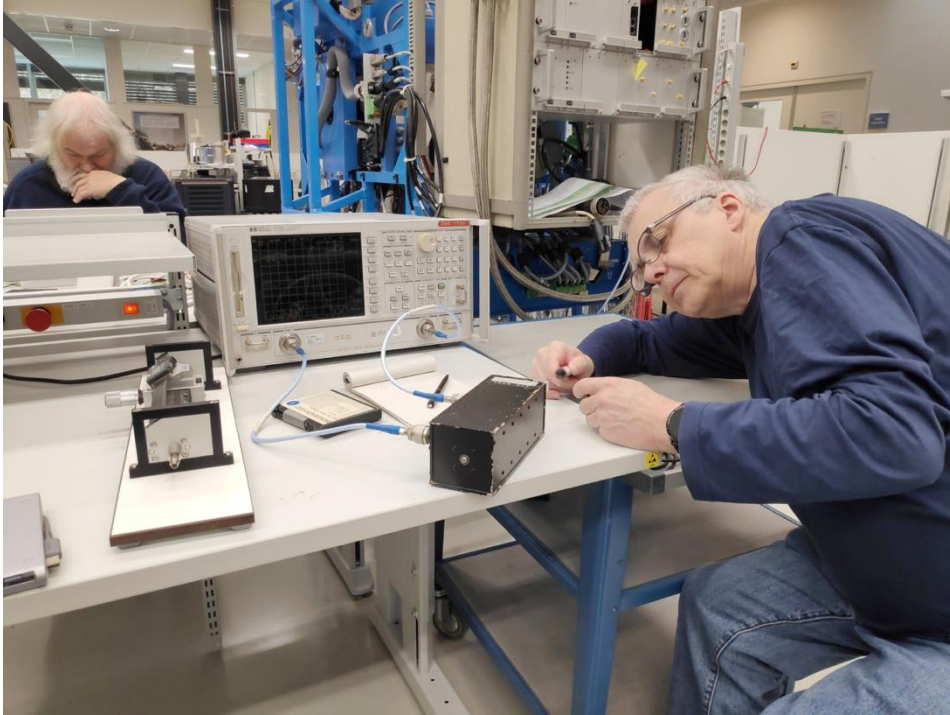
anon40327  
 anon36231  
 anon31883  
 NaomiNanoko  
 anon36231  
 pe1bmc  
 NaomiNanoko  
 anon40580  
 LA7TJA  
 anon43430  
 Harry  
 DL1KBL  
 PB4B  
 anon14574  
 12534  
 anon05848  
 anon56095  
 anon32958  
 SWL  
 anon36231  
 jumping beans  
 anon64346  
 NOS171  
 anon50563  
 9G1ZL  
 SAM-VK2BVS-SYDNEY  
 P19RD  
 anon30531  
 anon59147  
 LU6AES  
 anon25072  
 anon49611  
 anon36231

anon17717  
 anon38226

# WebSDR

DWINGELOO  
TRACKING





Extra bandpass filter, launch – 1 day



Fixing LNA, 5 minutes before AOS

**DWINGELOO  
TRACKING**



# In de media



RTV Drenthe



Dagblad van het Noorden



RTL Nieuws



NPO Radio 1



NPO Radio 2

# DWINGELOO ARTEMIS II TRACKING

167.016 points · all\_flagged\_rel.txt

subtract model annotations



DATA

DWINGELOO  
TRACKING

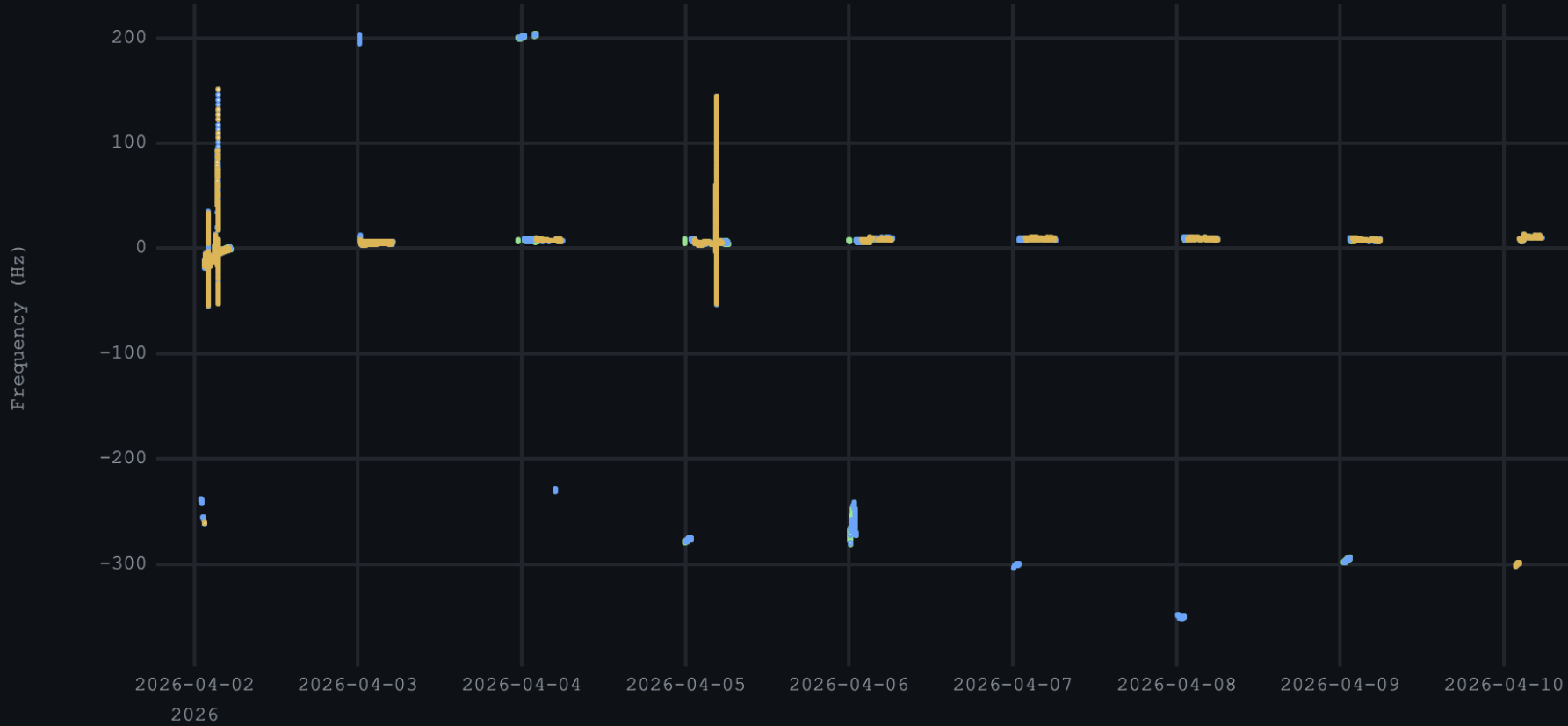


Data (CC-BY-SA 4.0): <https://data.camras.nl/artemis2>  
(werkt alleen in Firefox en Safari, sorry)

# DWINGELOO ARTEMIS II TRACKING

167.016 points · all\_flagged\_rel.txt

subtract model  annotations



DATA

DWINGELOO  
TRACKING



Data (CC-BY-SA 4.0): <https://data.camras.nl/artemis2>  
(werkt alleen in Firefox en Safari, sorry)

# DWINGELOO ARTEMIS II TRACKING

167.016 points · all\_flagged\_rel.txt

subtract model  annotations



DATA

DWINGELOO  
TRACKING



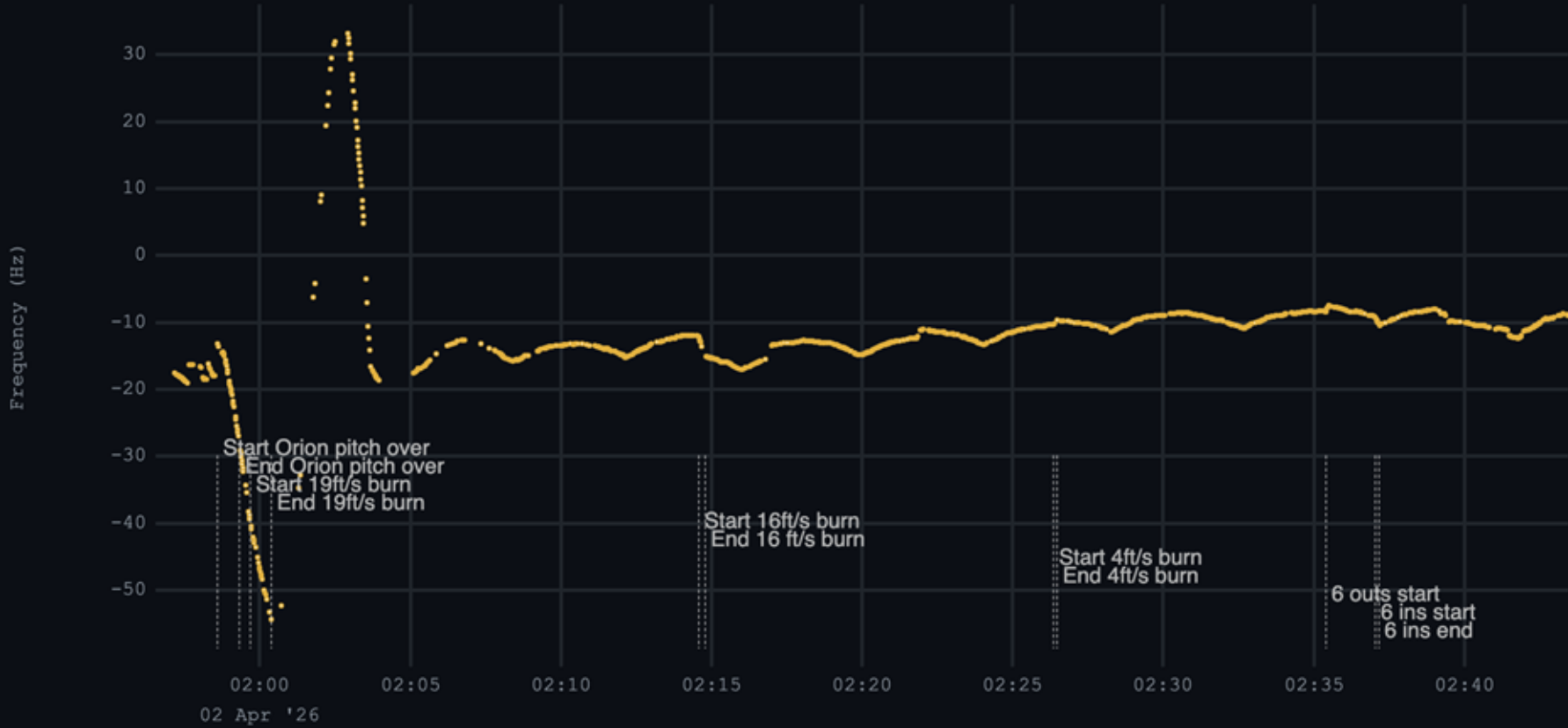
Data (CC-BY-SA 4.0): <https://data.camras.nl/artemis2>  
(werkt alleen in Firefox en Safari, sorry)

# DWINGELOO ARTEMIS II TRACKING

167.016 points · all\_flagged\_rel.txt

subtract model

annotations



DATA

DWINGELOO  
TRACKING



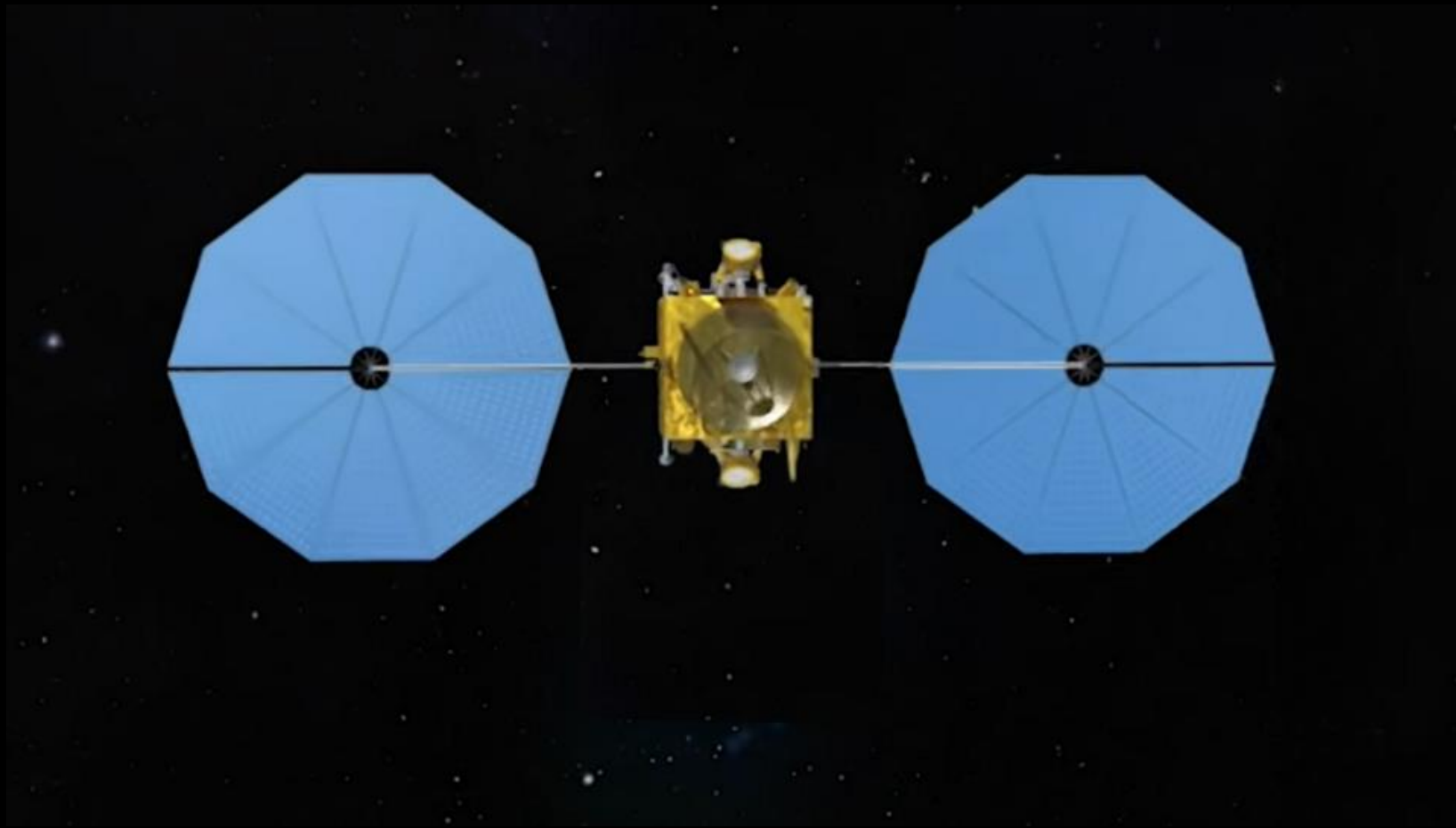
Data (CC-BY-SA 4.0): <https://data.camras.nl/artemis2>  
(werkt alleen in Firefox en Safari, sorry)

Dat was 't



Herman Smit  
John Nieuwerth  
@ 4 AM

# Bonus: Tianwen-2



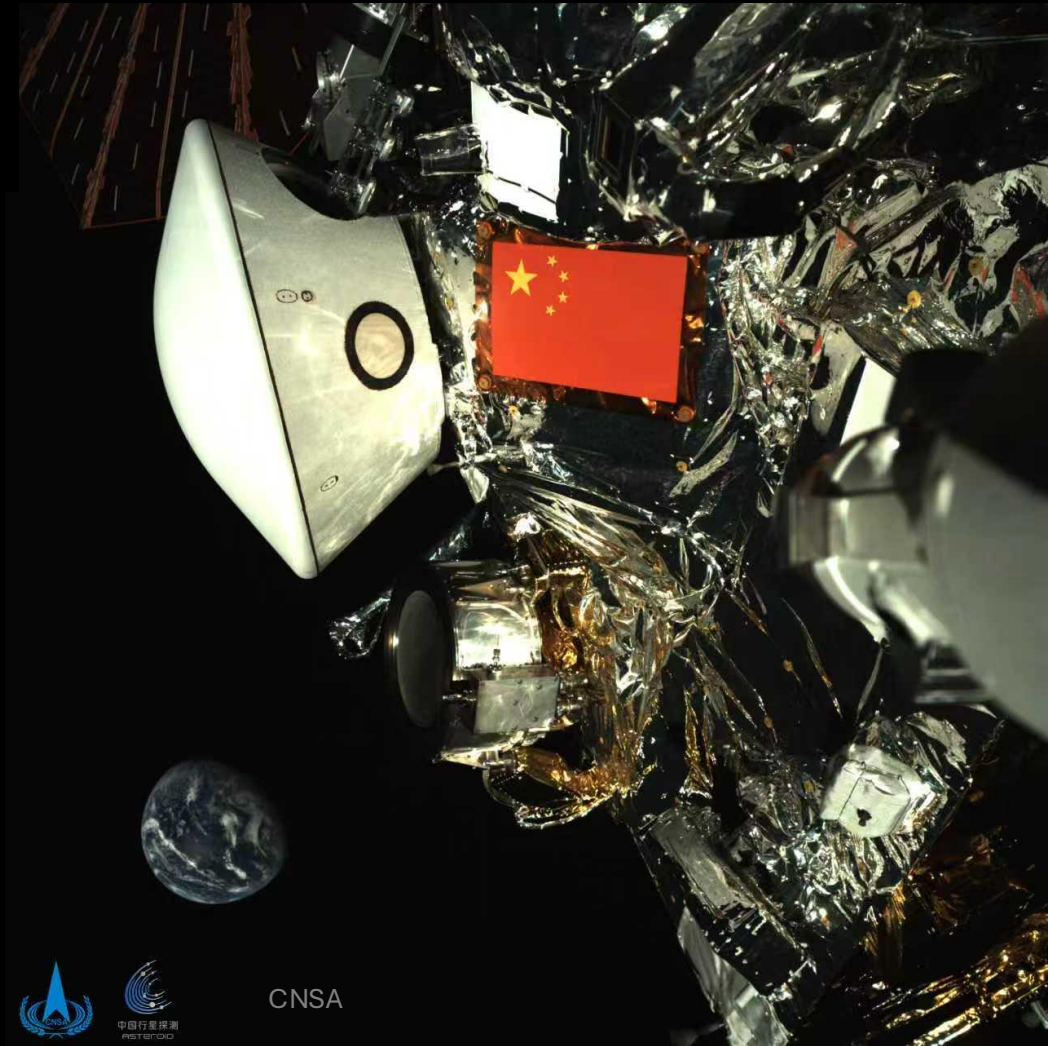
# Tianwen-2

- Sample return mission
- Mei '25: Lancing
- Juli '26: Aankomst Kamo'oalewa
- April '27: Vertrek Kamo'oalewa
- Nov. '27: Pakket naar aarde
- Jan. 2035: Aankomst PanSTARRS
- ...

我国小行星探测任务概述

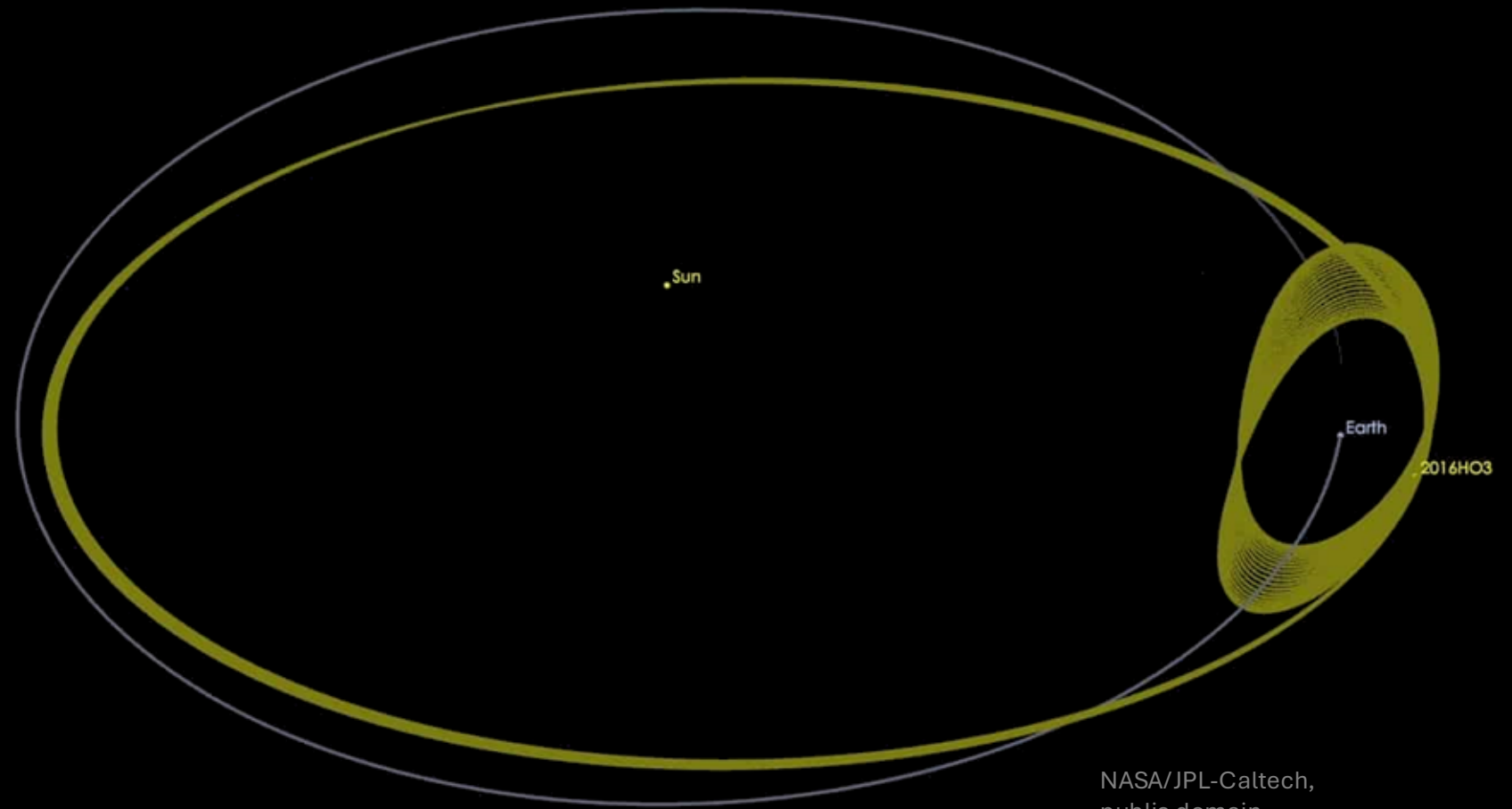
飞行过程-关键事件点

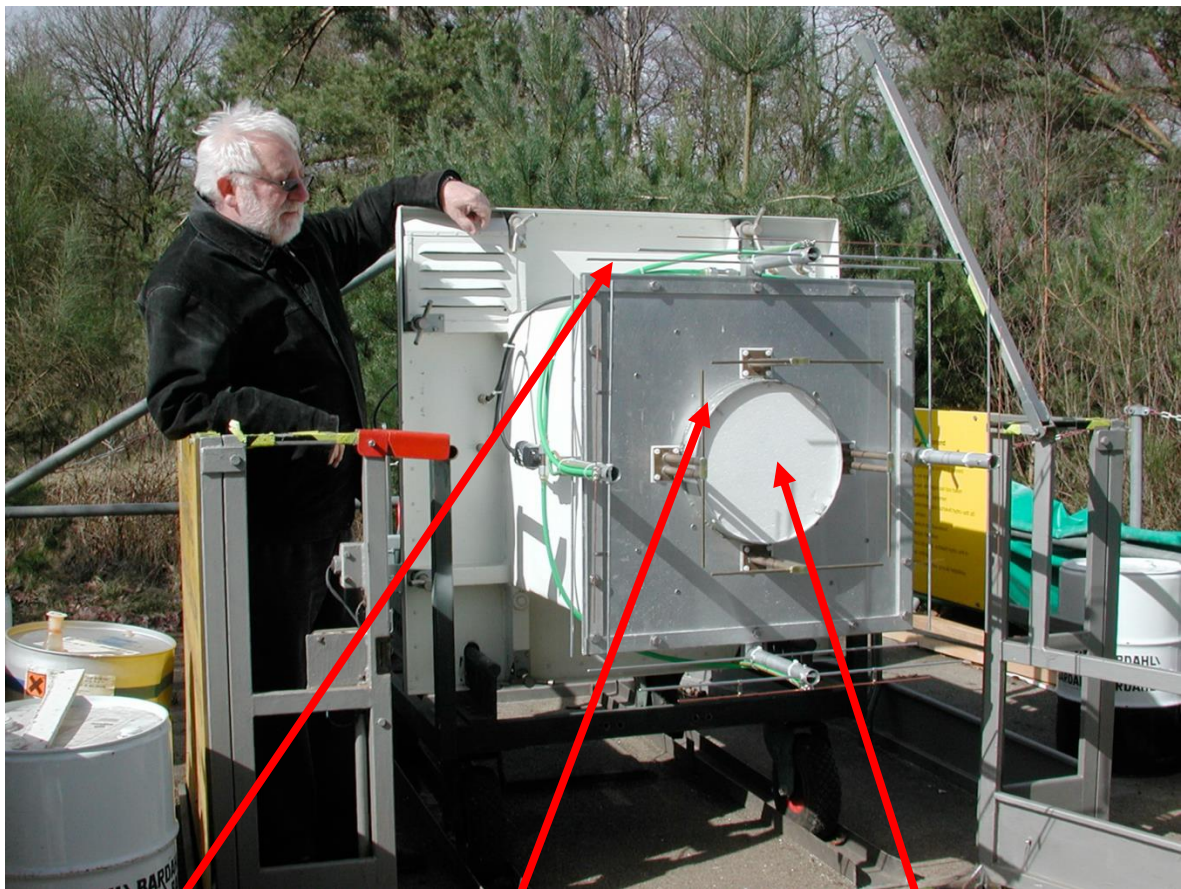
飞行事件	时间 (北京时间)	器地距离 (AU)	器日距离 (AU)	单程时延 (min)
火箭分离	2025/5/29	/	1	
深空机动	2025/10/30	0.31	0.99	
捕获机动	2026/6/7	0.26	1.06	
2016HO3交会	2026/7/4	0.28	1.01	
小行星近距离探测	2026/7~2027/4	0.11~0.31	0.89~1.11	最大2.42
离开2016HO3	2027/4/24	0.22	1.1	
舱器分离	2027/11/29	2.3万千米	0.99	
返回舱着陆	2027/11/29 17:15	-	-	
主器拉起机动	2027/11/29	1.7万千米	1	
311P转移	-	最近3.4	1~2.38	最大28.3
311P交会	2035/1/24	2.71	2.41	
311P近距离探测	2035/1~2035/4	2.1~1.64	2.41~2.44	



# Planetoïde Kamo'oalewa / 469219 / 2016 HO3

- Pseudo-maan
- 90m groot
- Rotatie elke 22 minuten
- 30 miljoen km ver weg





2m

70cm

23cm  
(21 cm)



13cm  
(2,1GHz)

3,5cm  
(8,4GHz)

9cm

### SatDump v2.0.0-alpha-4eee622f0 (vrtzmq/Release)

File Add ? Handler

VRT ZMQ Source

1 Decimatio

0.000000 MHz (LO c

**008.428.190.000 Hz**

2 Msps Samplera

localhost Address

0 Instance

50100 Port

Use Port

Stop

FFT

65536 FFT Size

121 FFT Rate

60 Waterfall I

-23.832 FFT Max

-112.336 FFT Min

61.626 Avg Num

Jet [lego11] Palette

Show Waterfall

Frequency Scale

Processing

Favourites

Tianwen-1 Link

DC Blocking

IQ Swap

Frequency Shift 0 Hz

Stop

Recording

Tracking

VFOs

Info Progress -nan%, SNR : 13.868855dB, Peak SNR: 15.371893dB

PM Demodulator

CCSDS r=1/2 Concatenated Decoder

Signal	Viterbi
Freq : -1.7506 kHz	State : <b>SYNCED</b>
SNR (dB) : 14.793	BER : 0.004883
Peak SNR (dB) : 15.372	
Avg SNR (dB) : 14.717	
	Deframer
	State : <b>NOSYNC</b>
	Reed-Solomon
	RS : 0

module>

048, 0.936, -

18, 0.936, -1

18, 0.930, -1

18, 0.926, -1

048, 0.926, -

048, 0.921, -

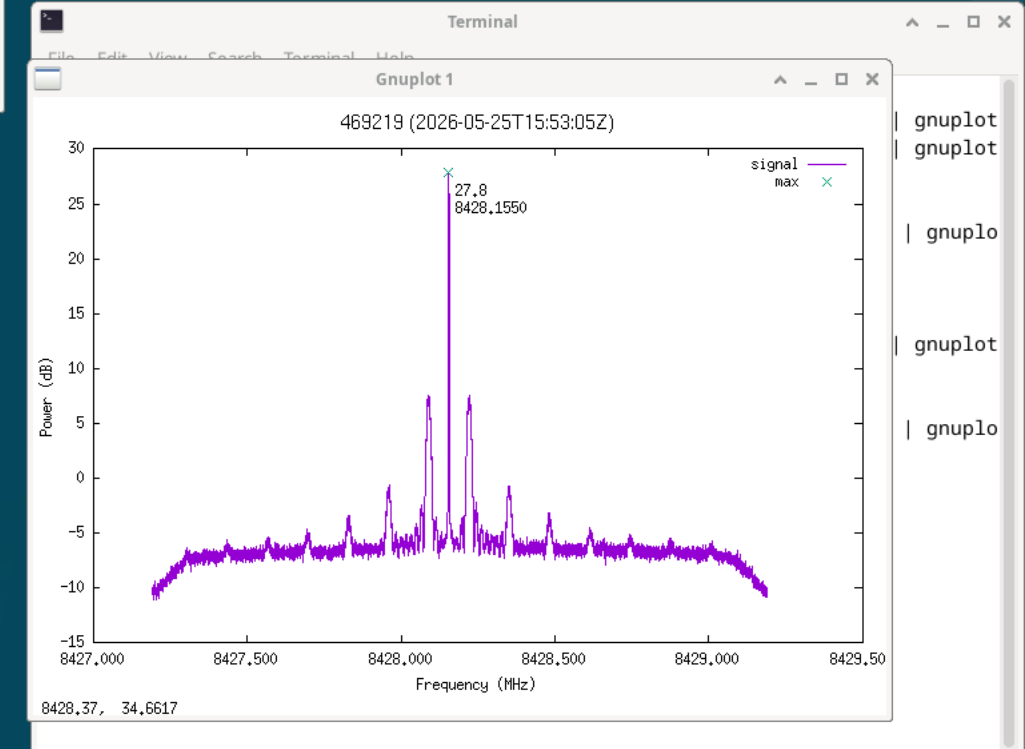
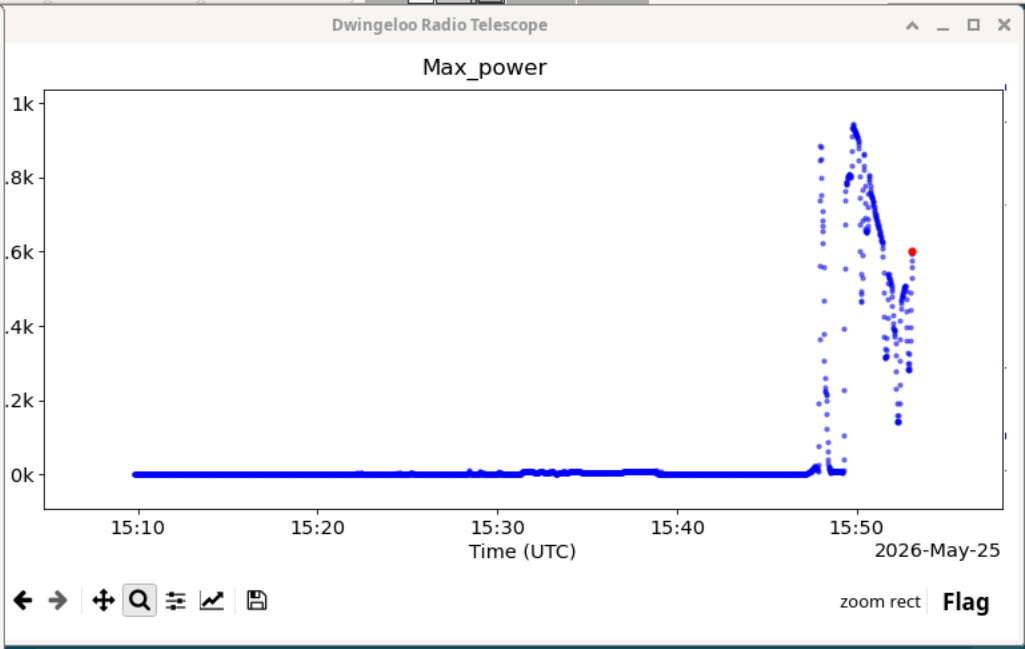
048, 0.913, -

048, 0.909, -

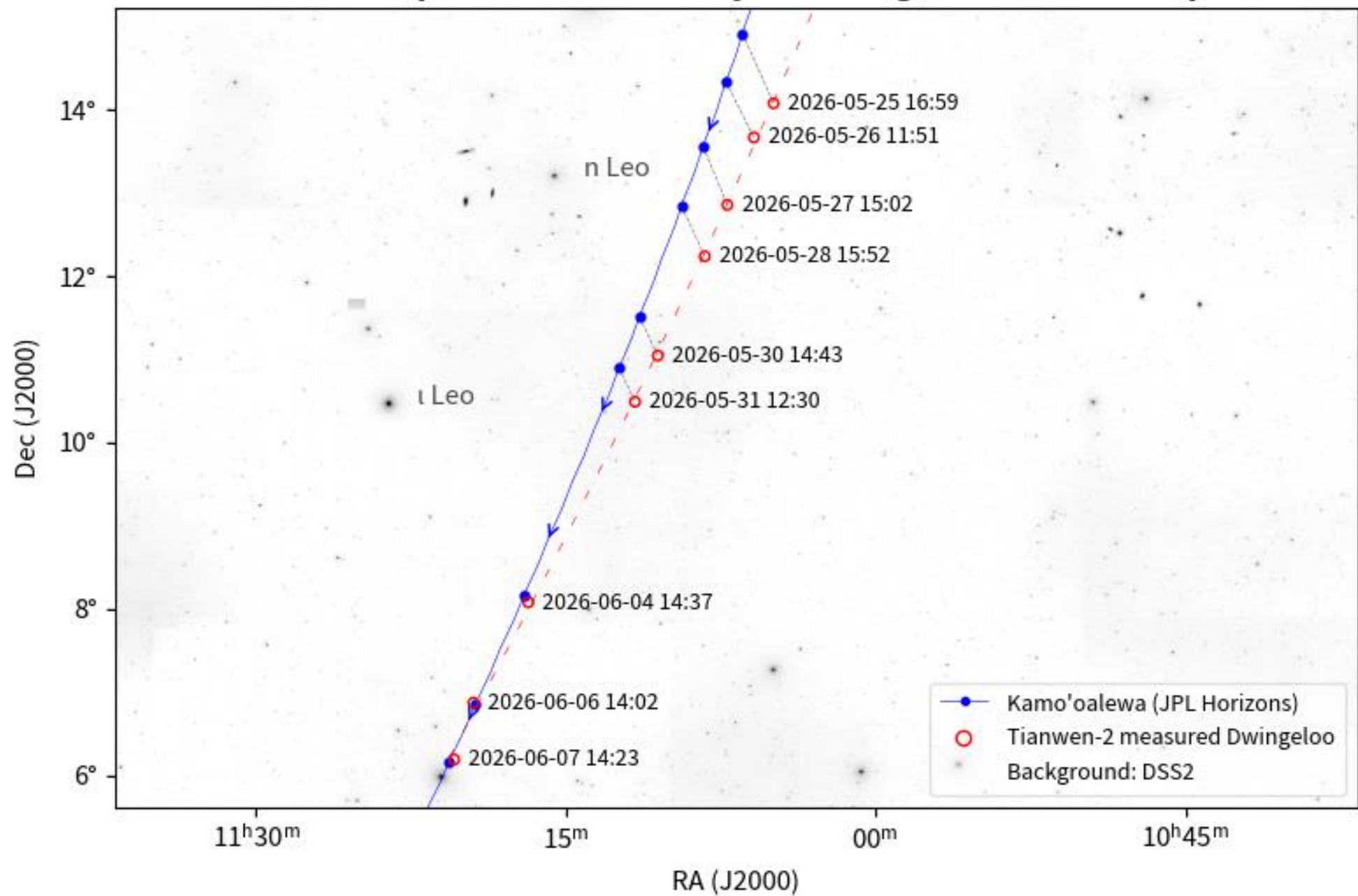
048, 0.907, -

18, 0.905, -1

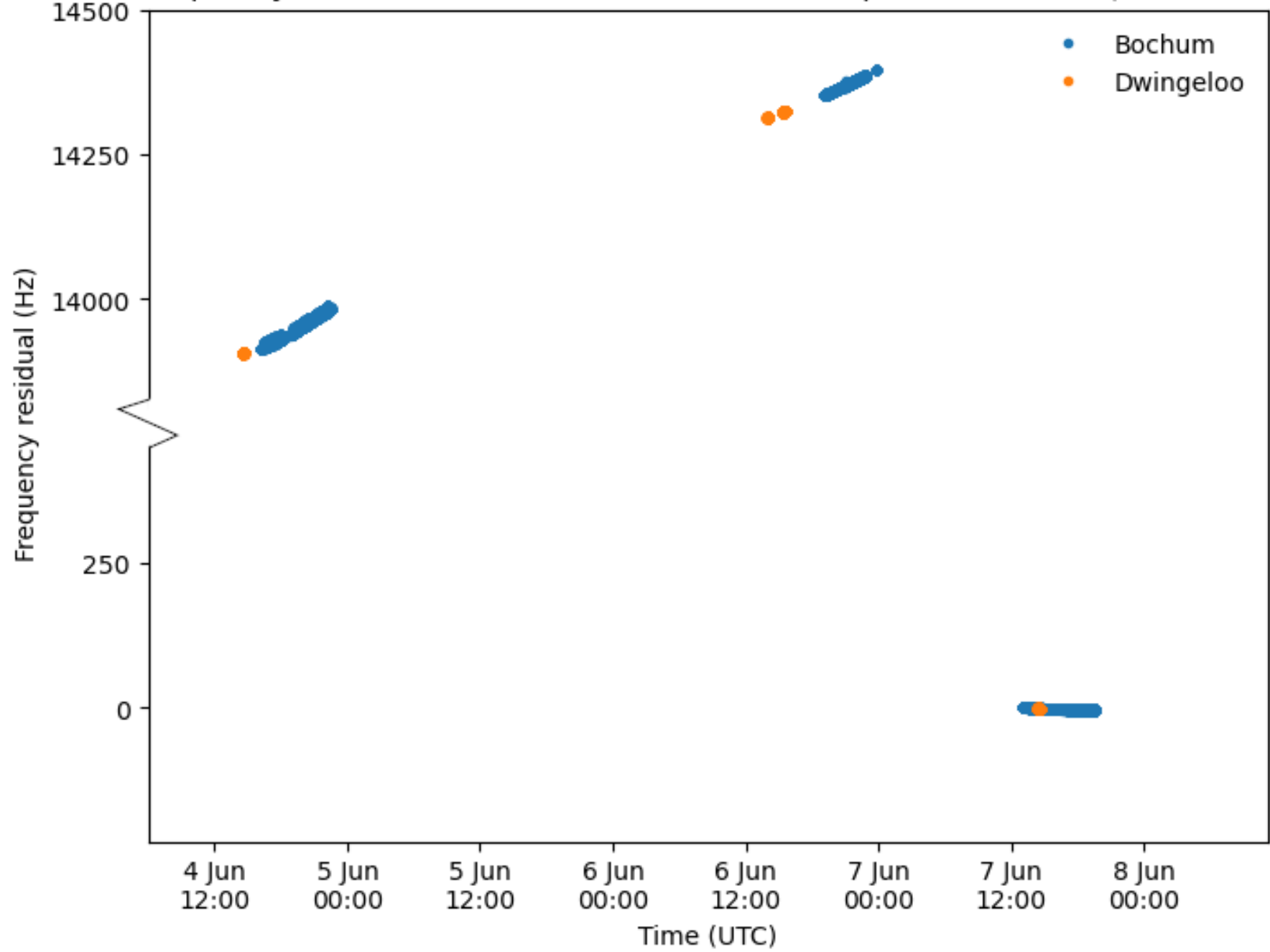
048, 0.905, -



# Tianwen-2 position measured by the Dwingeloo radio telescope



Frequency residual w.r.t. Kamo'oalewa, base freq 8428.201 MHz (estimated)



Tianwen-2 nu live online via  
<https://www.youtube.com/@amsatdl/live>

