Novel Approaches to Solar Flare Forecasting and Space Weather Monitoring: Results from the FLARE and IONEX Projects

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“Ventspils International Radio Astronomy Centre”
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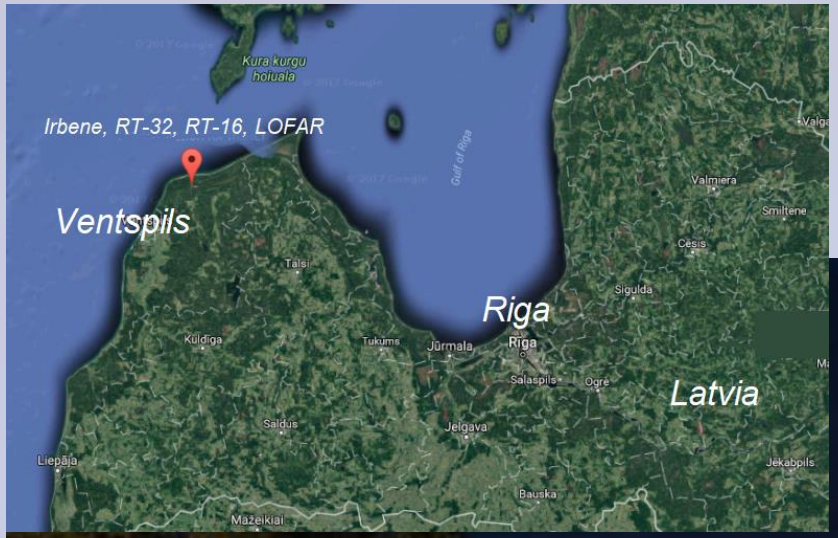
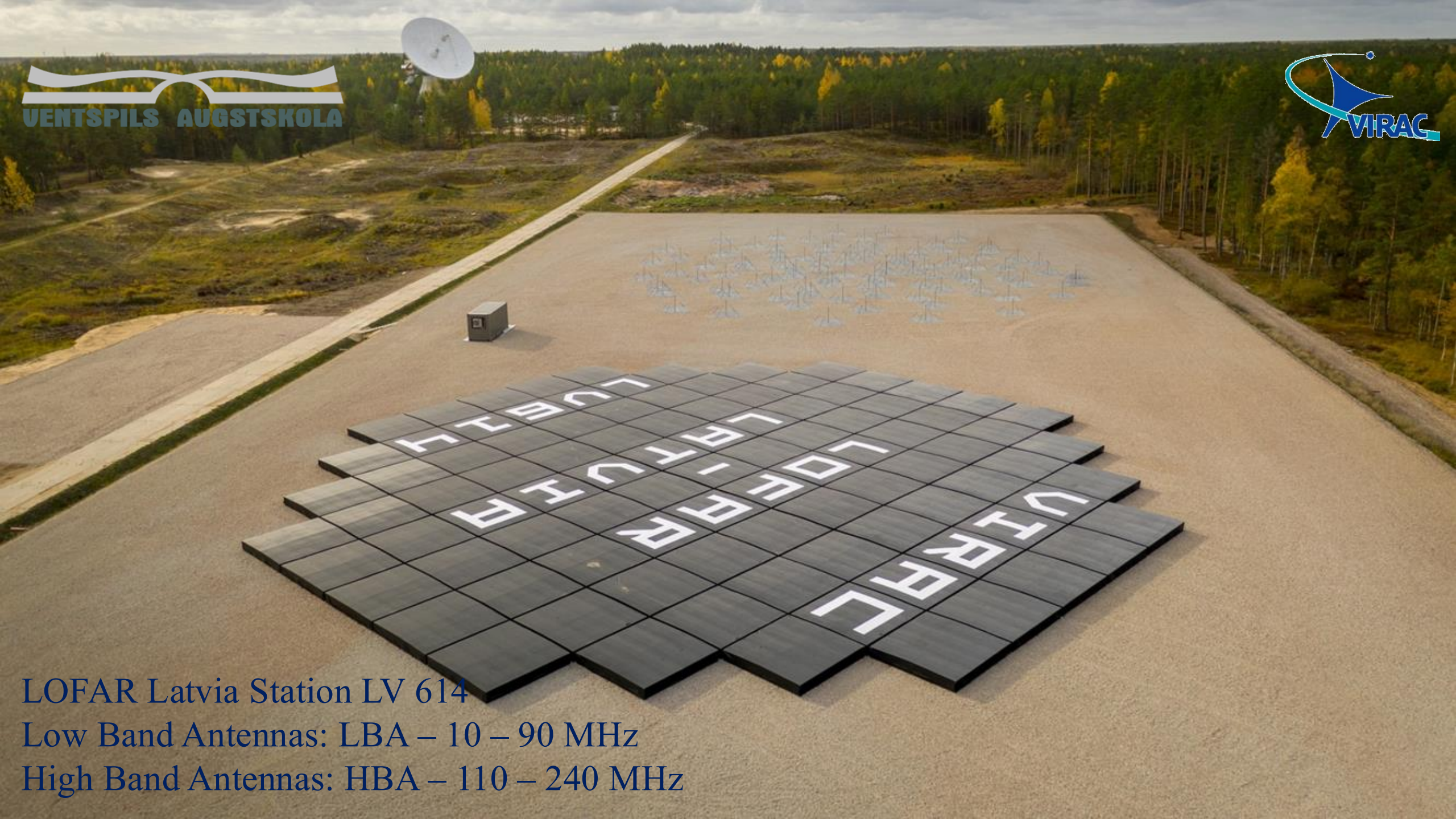


ERI VIRAC is:

Full member of EVN European VLBI Network
Member of JIV-ERIC
Observer of LOFAR ERIC





LOFAR Latvia Station LV 614
Low Band Antennas: LBA – 10 – 90 MHz
High Band Antennas: HBA – 110 – 240 MHz

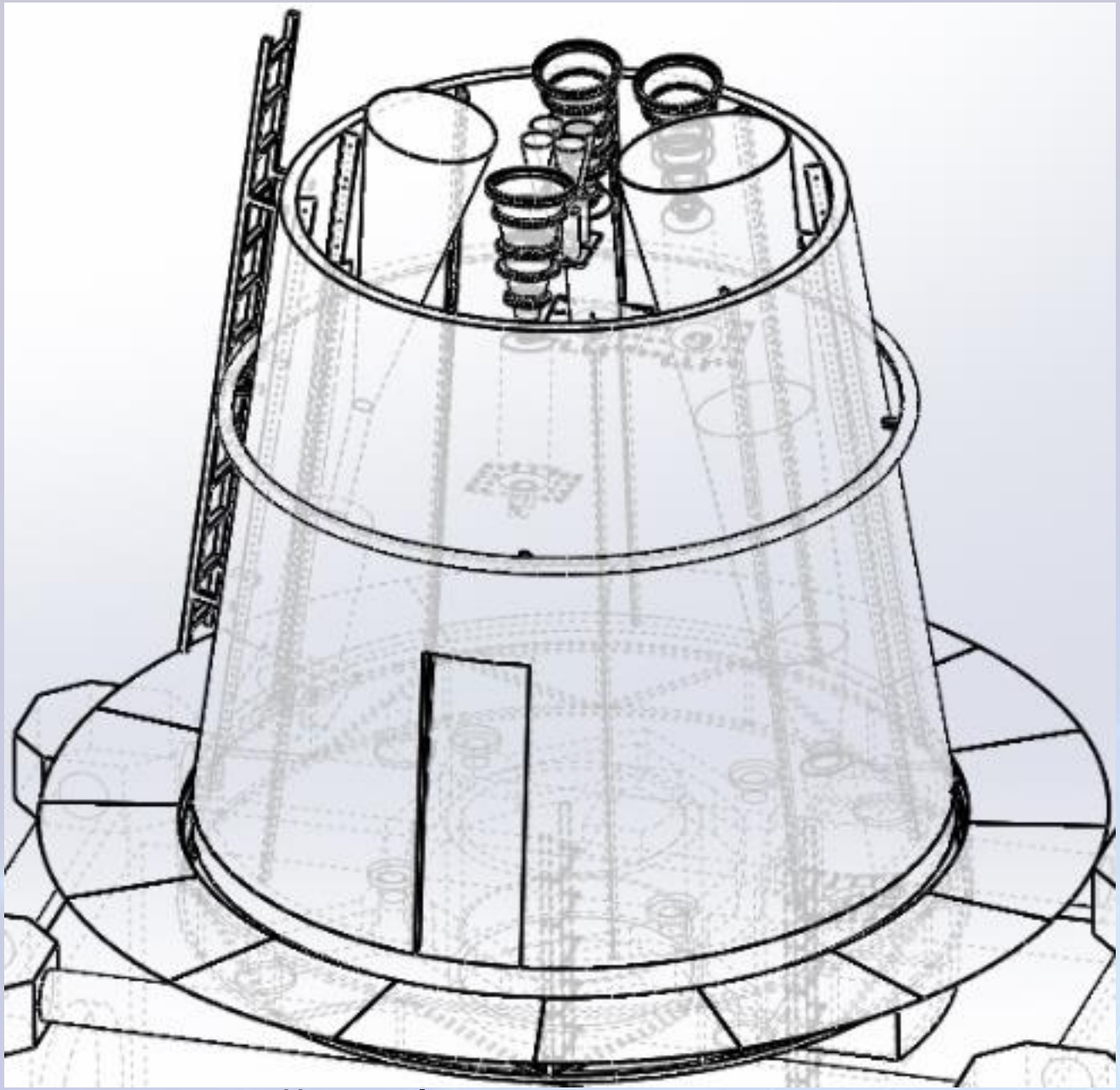
Main ERIC VIRAC activities

- VLBI Activity – EVN (JIVE ERIC)
- LOFAR Activity (LOFAR ERIC)
- Studies of Interstellar Dust Processes
- Observations of Space Masers
- Deep space comunictions
- Multi-Wavelength Radio Spectral-Polarimetric Observations of the Sun and Ionosphere



RT-32:







Agris Bērziņš et al





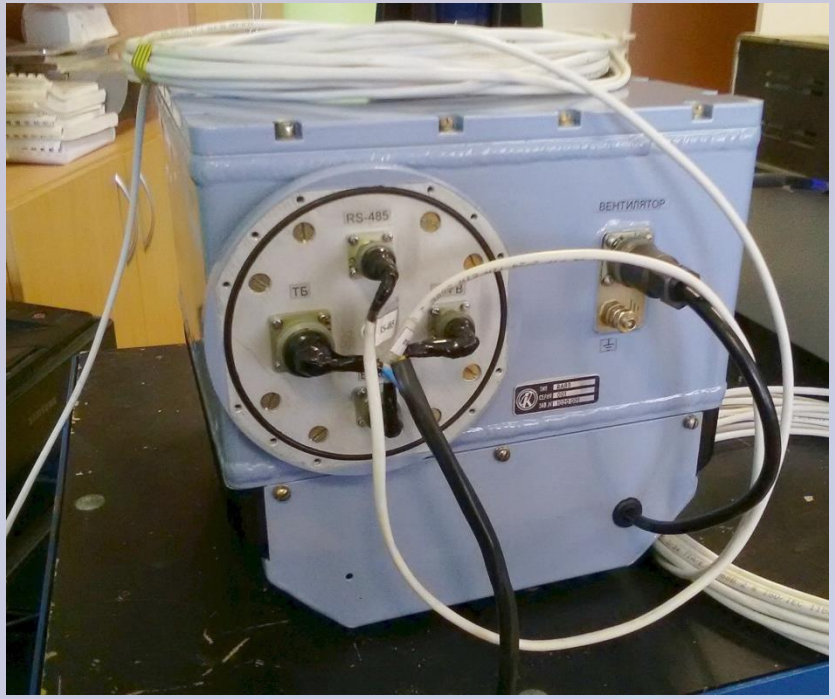


Microwave observations of the Sun with RT-32: Hardware

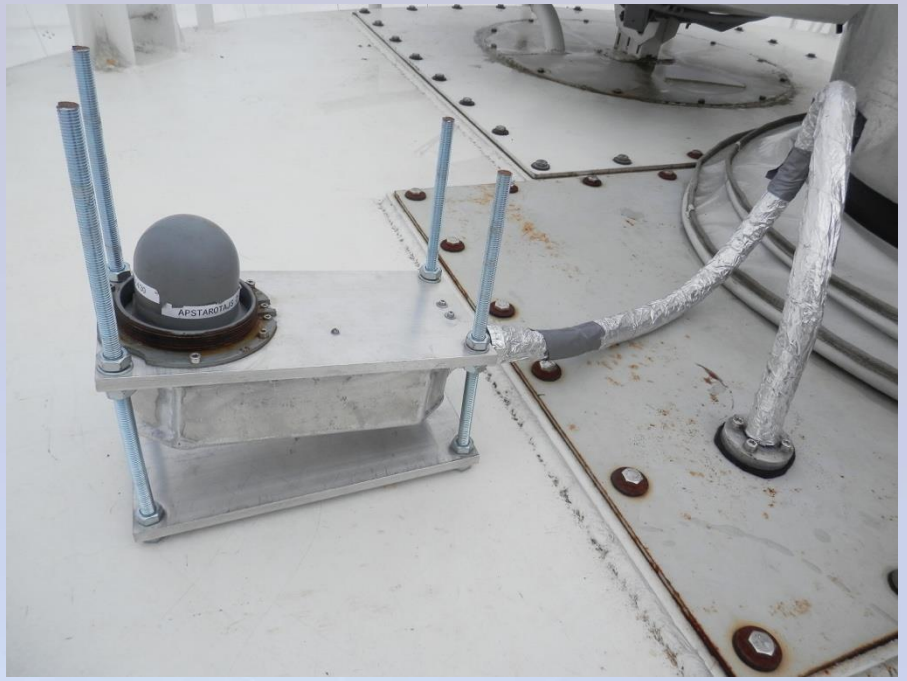


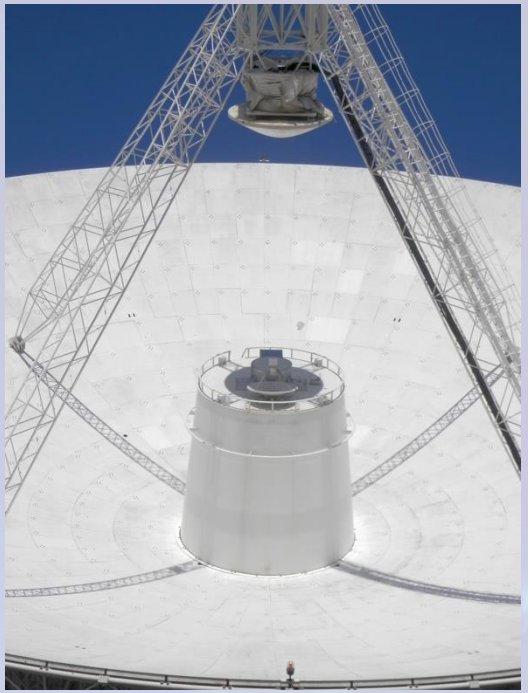
VIRAC RT-32 radio telescope after reconstructions of the central cabin and the secondary mirror

Microwave observations of the Sun with RT-32: Hardware









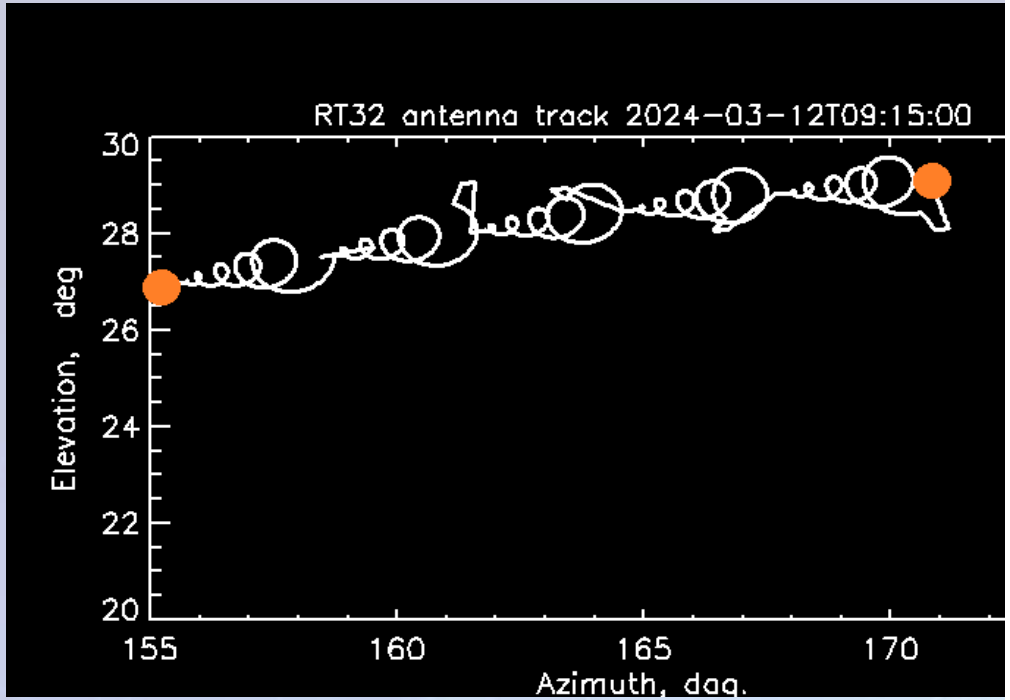
Microwave observations of the Sun with RT-32: Hardware

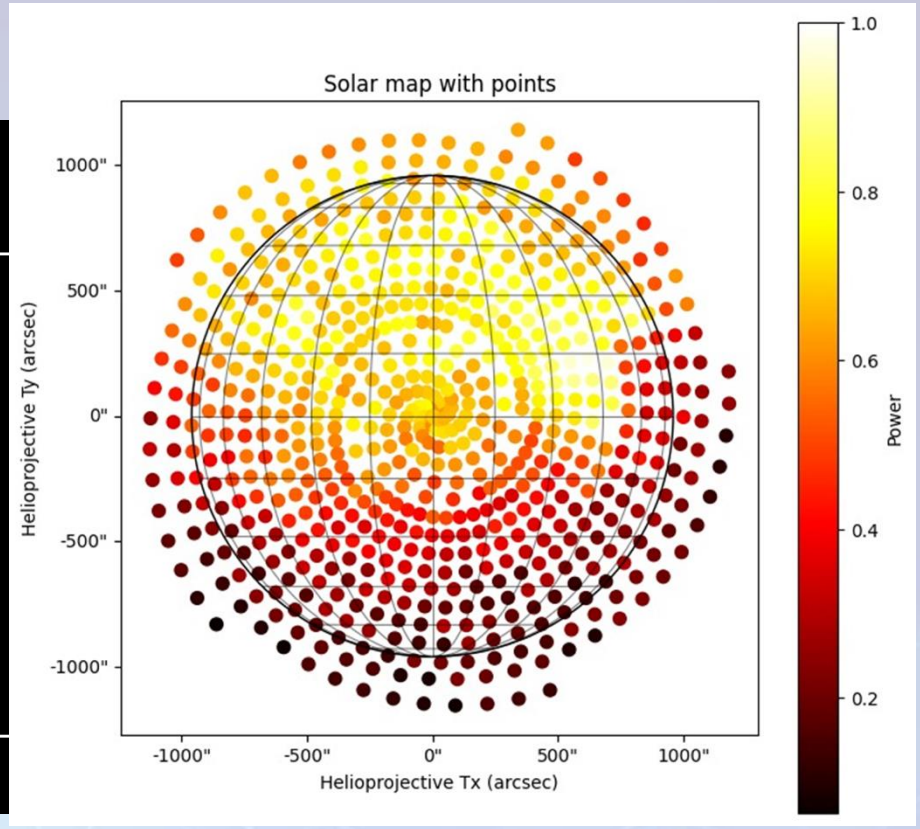
Some parameters of multichannel low noise spectral polarimeter (LNSP4)
The distribution of channel's frequencies corresponds to the frequency grid of RATAN-600

Frequency range	4.07-14.2 GHz (2.1-7.6cm)
Number of channels	12
Band widths	200-800 MHz
Polarization	RCP and LCP
S/N ratio ($T_{quietSun} / 3\sigma T_{noise}$)	>22-24 db
Dynamic range ($T_{saturation}/T_{quiet\ Sun}$)	>32 db
Sampling rate	>10 sample/ sec
Sensitivity	>80 dbm
ADC	16 bit
Antenna HPBW	2.3 – 8.2 arc min
Internal noise generator	yes
Internal thermal stabilization	yes

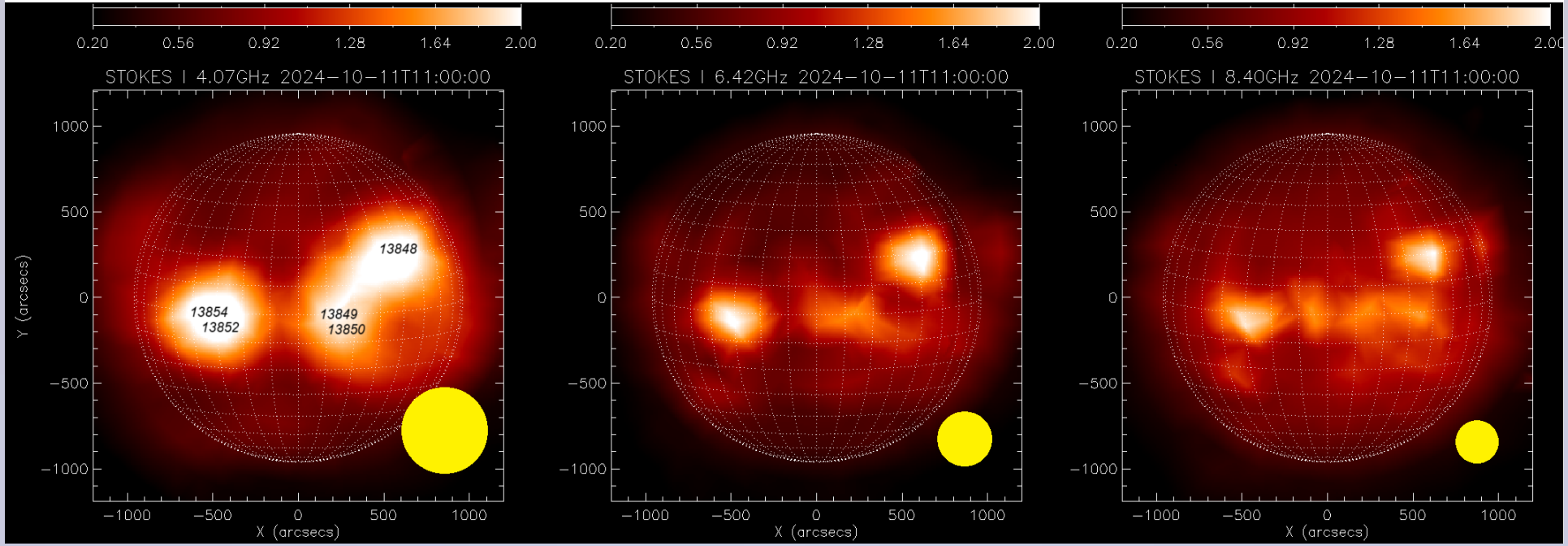
1	2	3	4	5	6	7	8	9	10	11	12
4.07	4.60	5.70	6.40	6.96	7.83	8.40	9.35	9.80	10.98	11.90	14.28

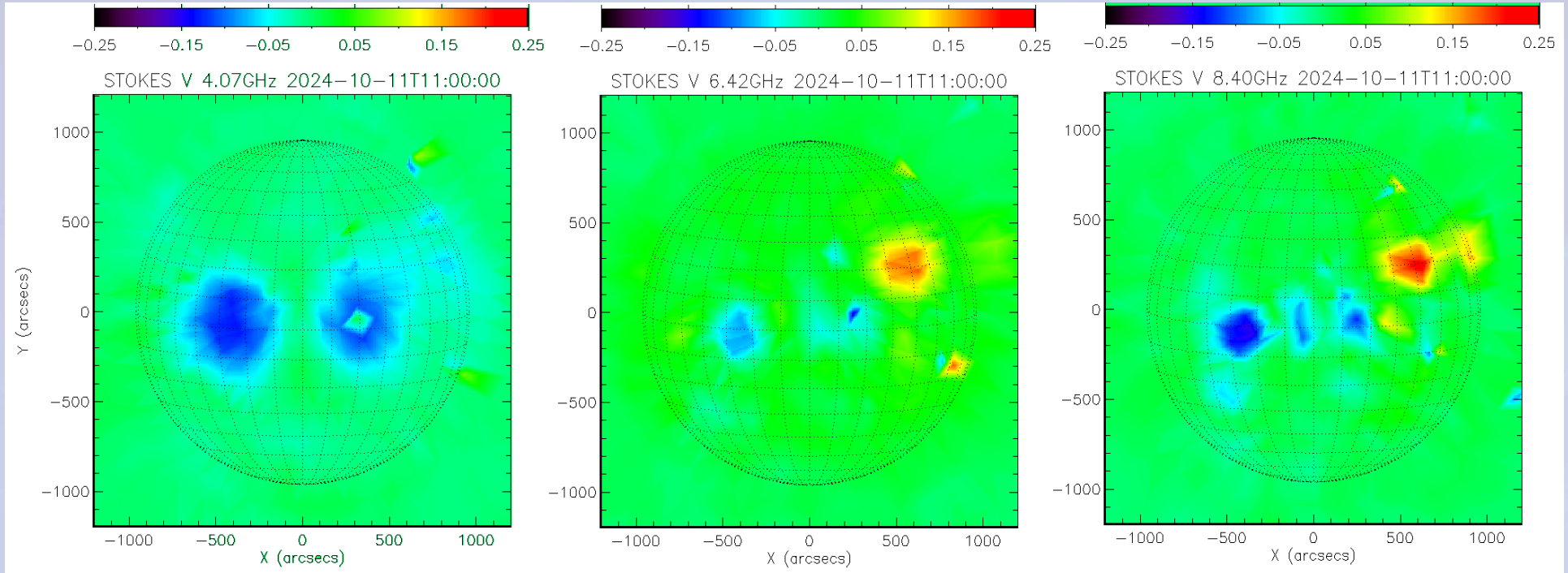
Microwave emission Stokes I and V 2D mapping: Spiral scanning of the whole disk of the Sun





E. Aguirre, W. Bouzarhoun (2024)

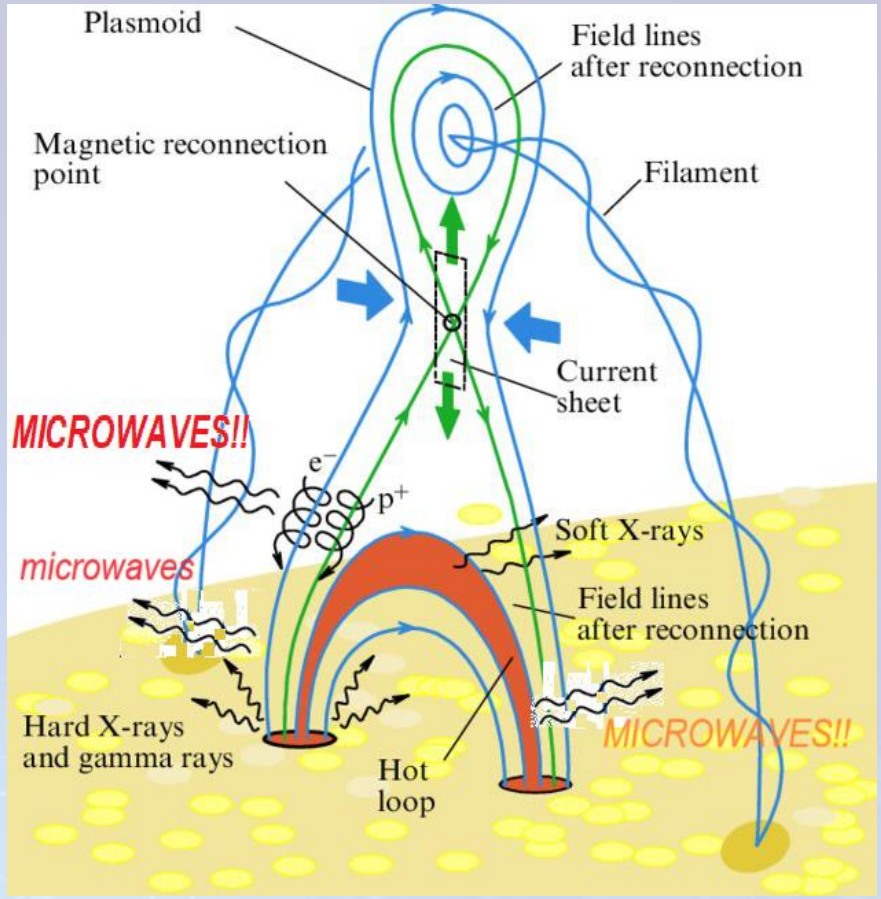

0.20 0.56 0.92 1.28 1.64 2.00
STOKES I 4.07GHz 2024-10-11T11:00:00
13848
13854
13852
13849
13850
STOKES I 6.42GHz 2024-10-11T11:00:00
STOKES I 8.40GHz 2024-10-11T11:00:00
Y (arcsecs)
X (arcsecs)
1000
500
0
−500
−1000


−0.25 −0.15 −0.05 0.05 0.15 0.25
STOKES V 4.07GHz 2024-10-11T11:00:00
STOKES V 6.42GHz 2024-10-11T11:00:00
STOKES V 8.40GHz 2024-10-11T11:00:00
Y (arcsecs)
X (arcsecs)
1000
500
0
−500
−1000

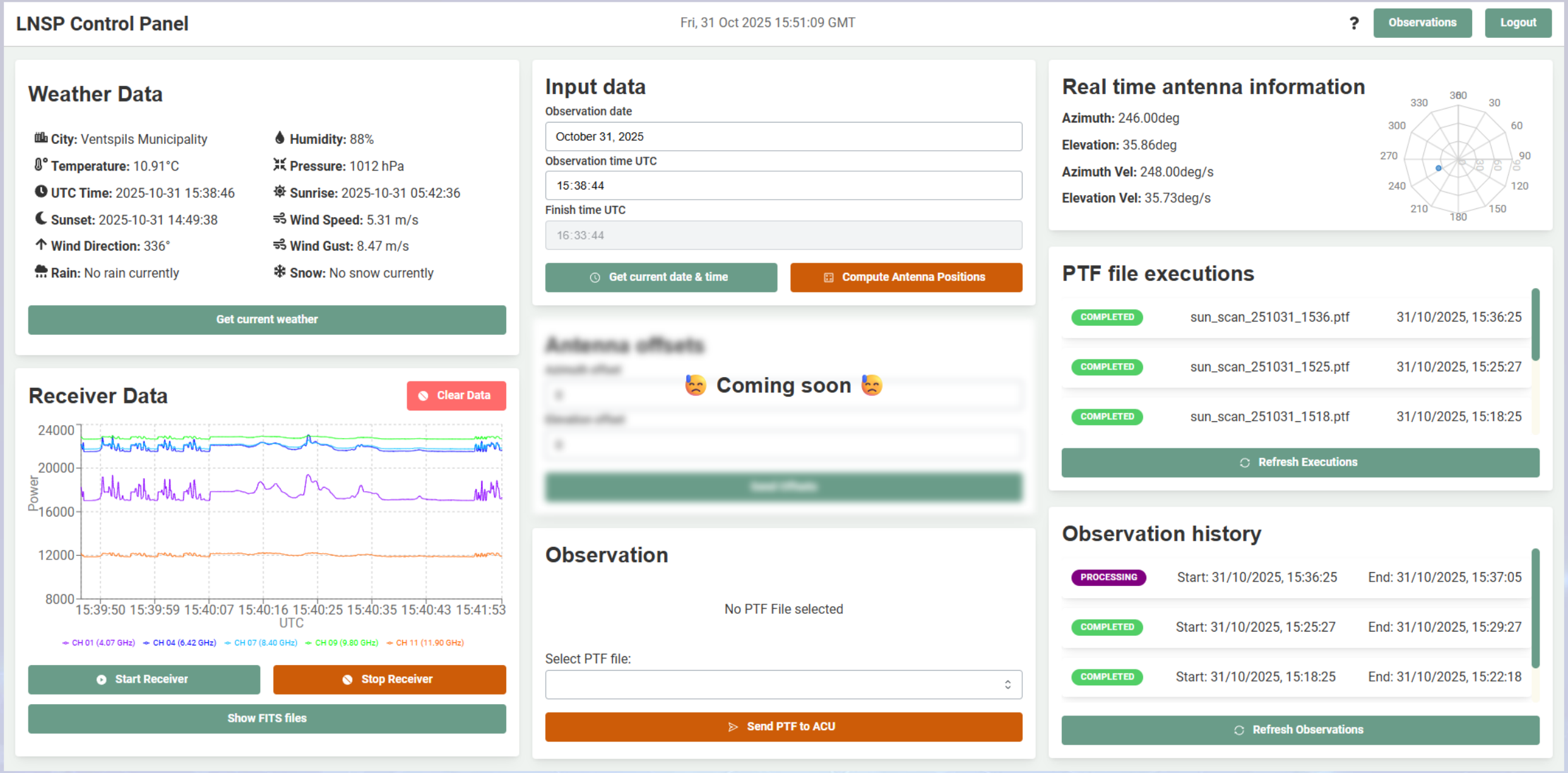
Monitoring of the microwave full flux of separate AR's with a high probability of solar flares

Studies of quasi periodic pulsations (QPP) of the microwave flux of active regions as precursors of solar and stellar flares

- Observations of fluctuations of microwave emission of solar active regions preceding II and III type radio bursts
- Detection of quasi periodic pulsations (QPP) of microwave flux of active regions as precursors of solar flares (“Sun as a star”)
- Studies of events and emergences of coronal loops before and after flares in the corona at different distances above the photosphere based on microwave observations



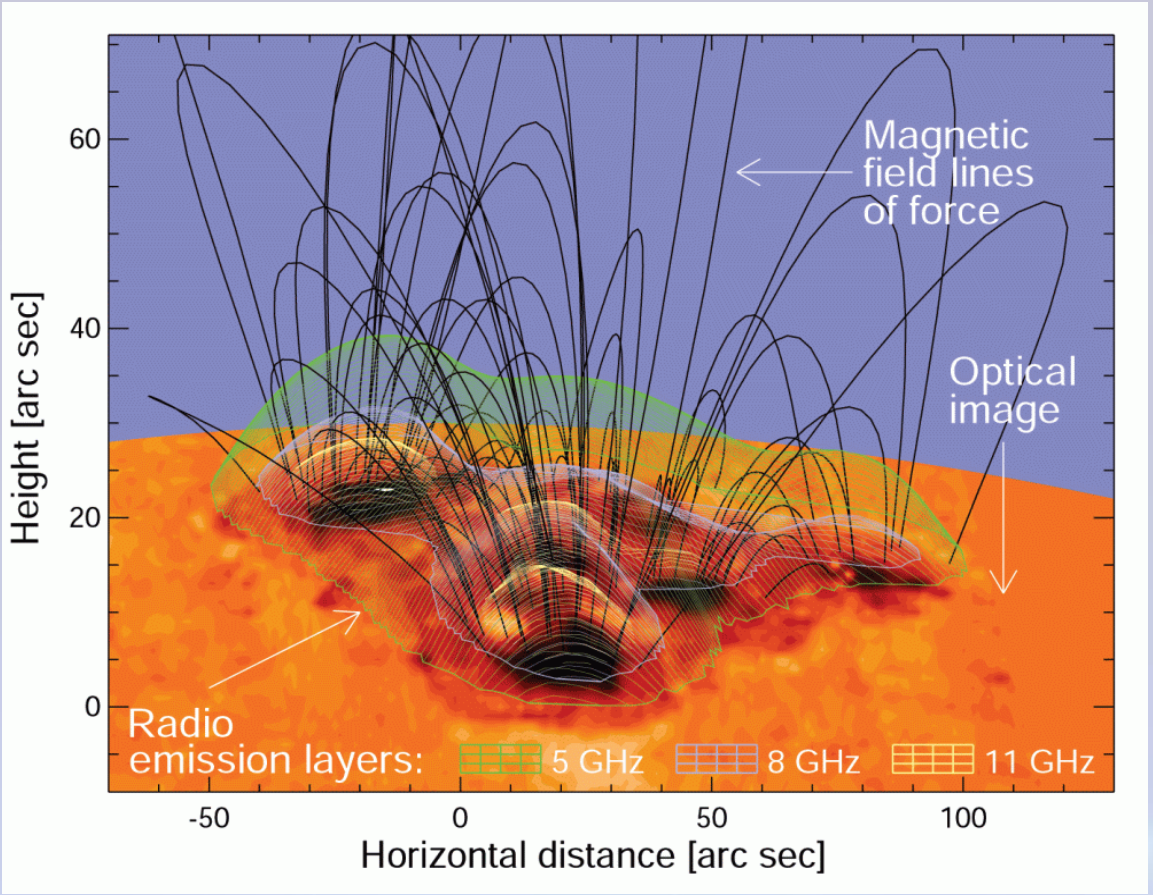
Shibata, Magara, 2011, V Dominguez et al, 2012, image G. Holman and NASA



Snapshot of the developed web interface showing the solar map database.

E. Aguirre, POS, vol. 520, (BAASP 2025)001

Why microwaves?



The simulation of an active region structure (Lee et al. 1994,1997)

Taking into account that the microwave polarized emission of different wavelengths is emitted from different heights above the photosphere the analysis of microwave polarized emission's spectra allows to measure directly plasma parameters and magnetic fields inductions over the upper chromosphere and the lower corona.

Feasible tasks and problems

Observations of large-scale coronal areas

- *Studies of radio brightness of the quiet Sun and coronal holes*
- *Analysis of coronal hole-like areas associated with open magnetic fields which could be expected as sources of the slow solar wind*
- *Revealing the large-scale coronal loops as immediate relatives of distant active regions so as to reproduce sympathetic solar flares*

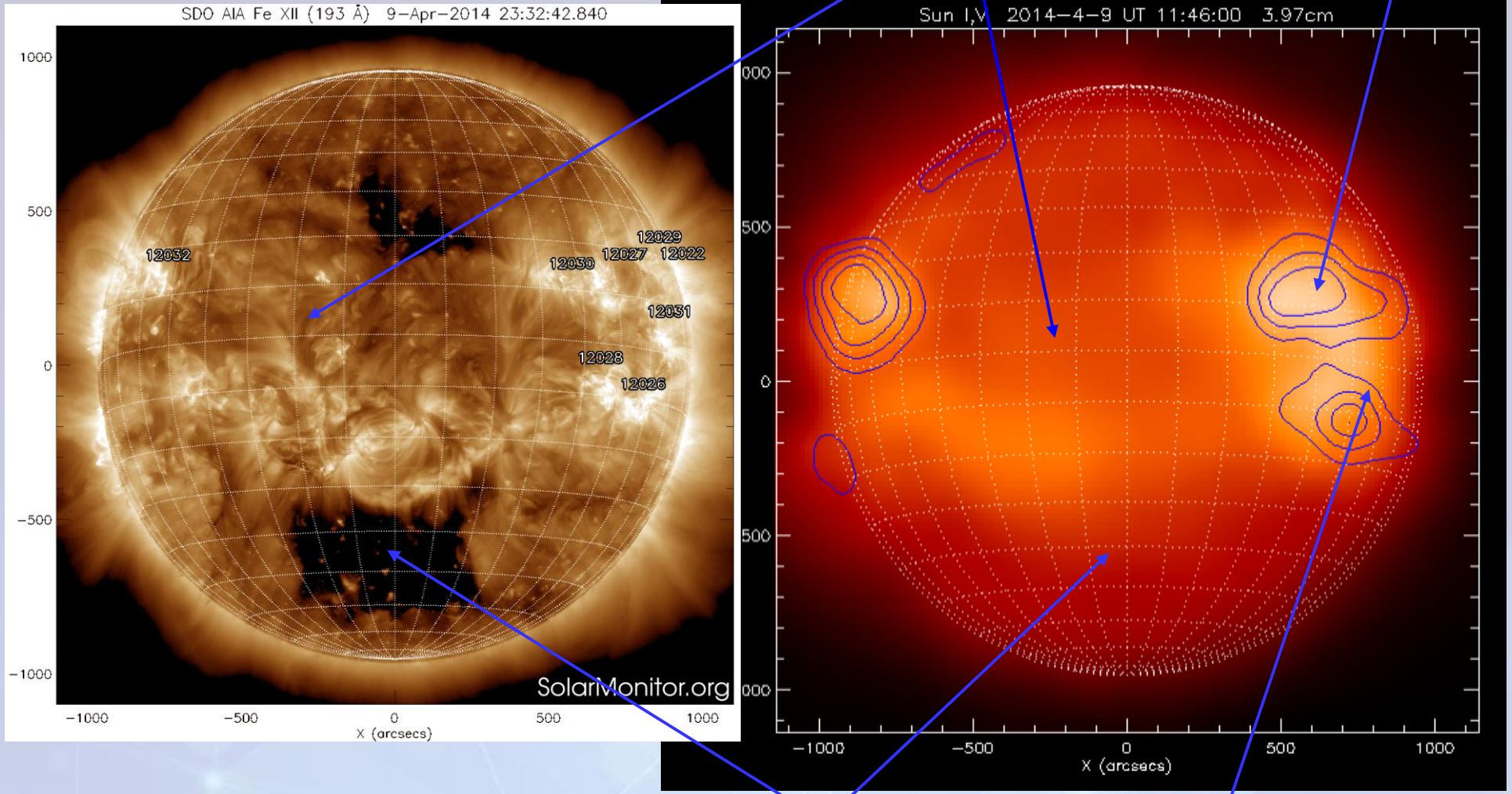
Coronal magnetography

- *Analysis of the microwave polarized emission of solar active regions for revealing and studies of coronal magnetic fields based on the quasi-transverse emission's propagation*

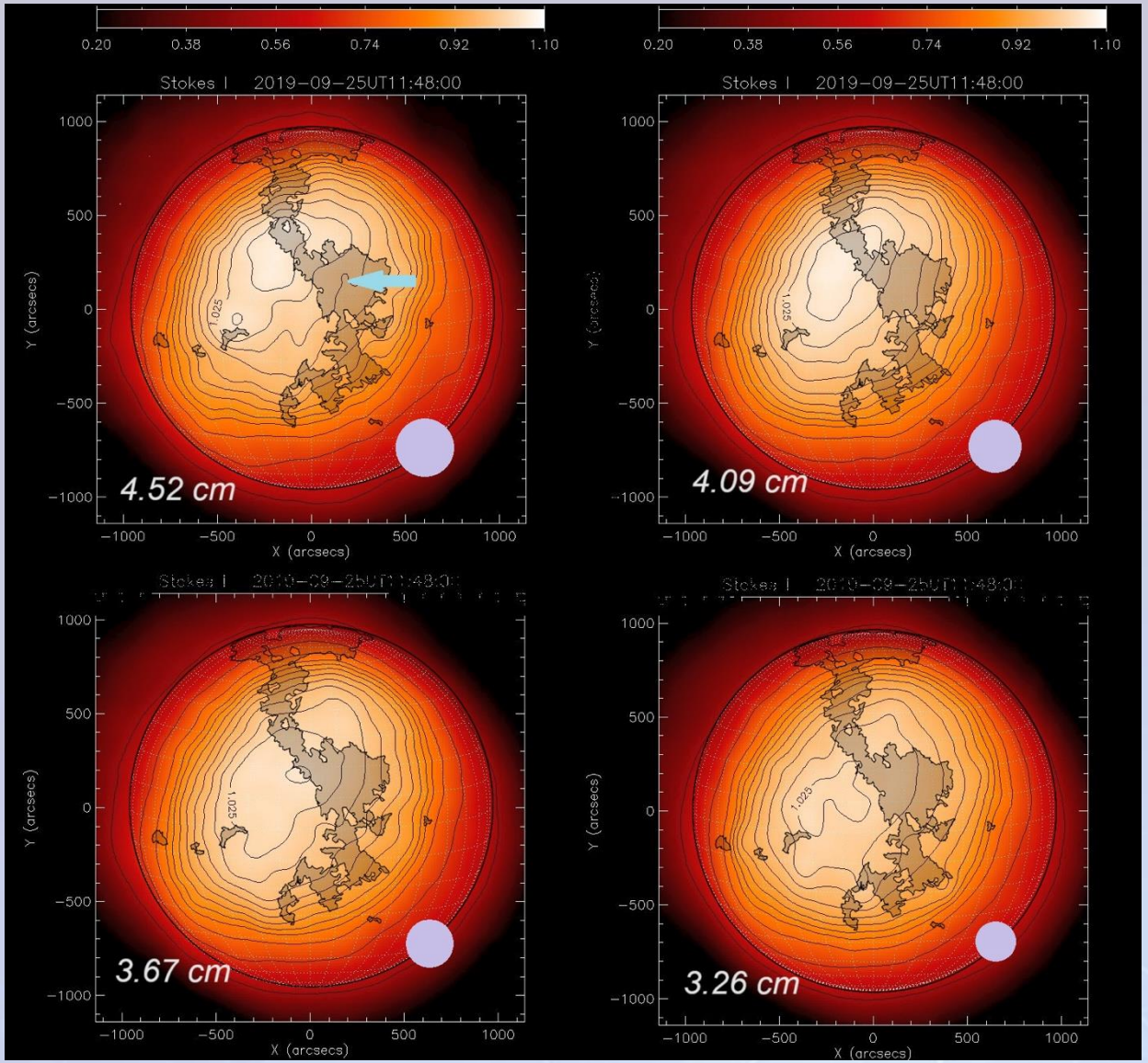
Microwave flux fluctuations in local sources

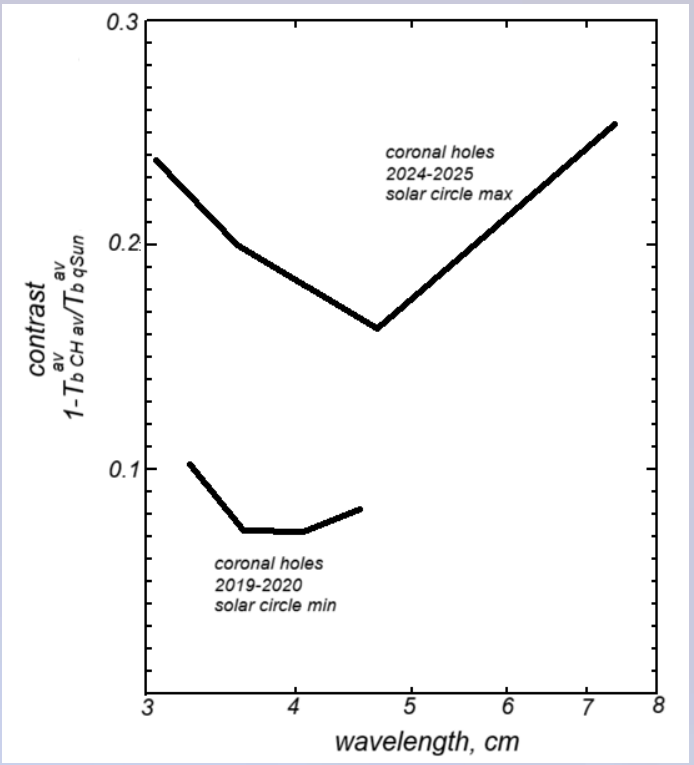
- *Analysis of the microwave flux fluctuations resulting by magnetic field emergencies in active regions*
- *Analysis of microwave flux quasi periodic pulsations (QPP) as precursors of solar flares*

The visibility of the big coronal hole in microwaves.
2014-04-09, VIRAC RT-32, Stokes I, 3.97 cm



Visibility of coronal holes in microwaves in 25th solar circle

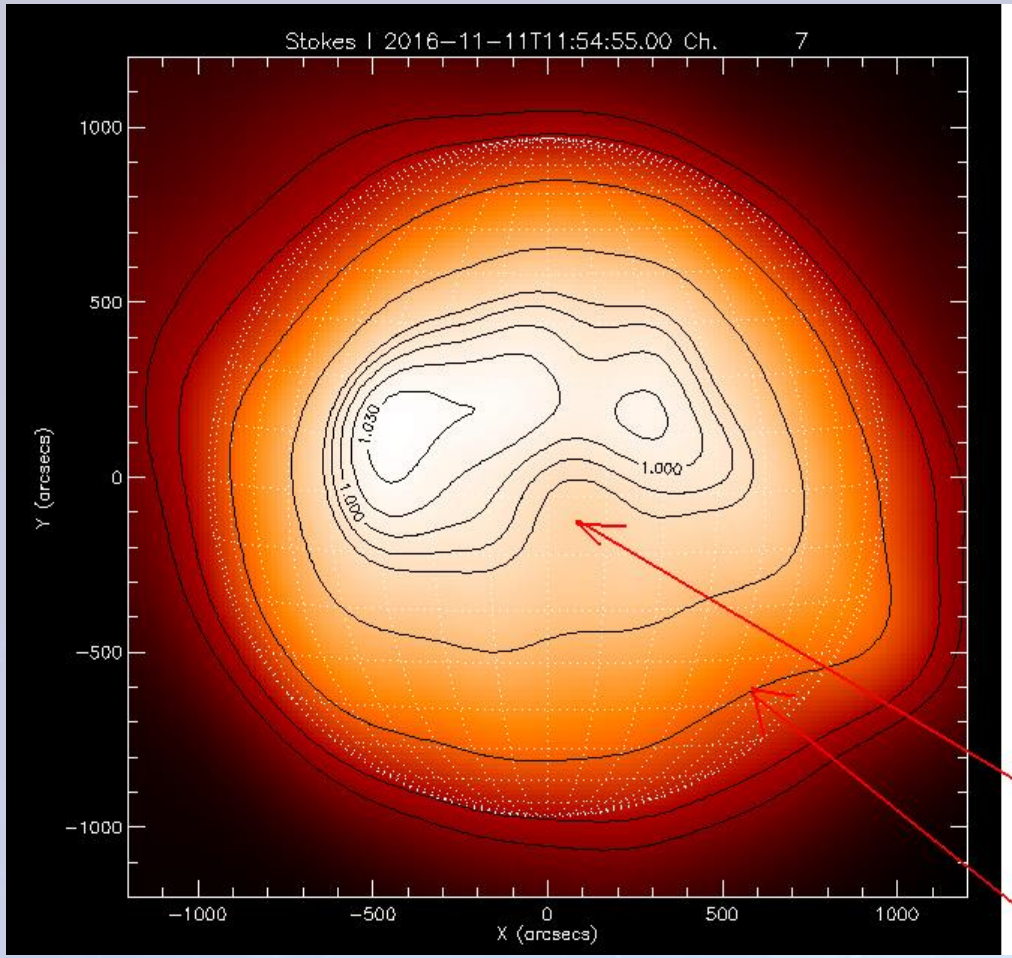




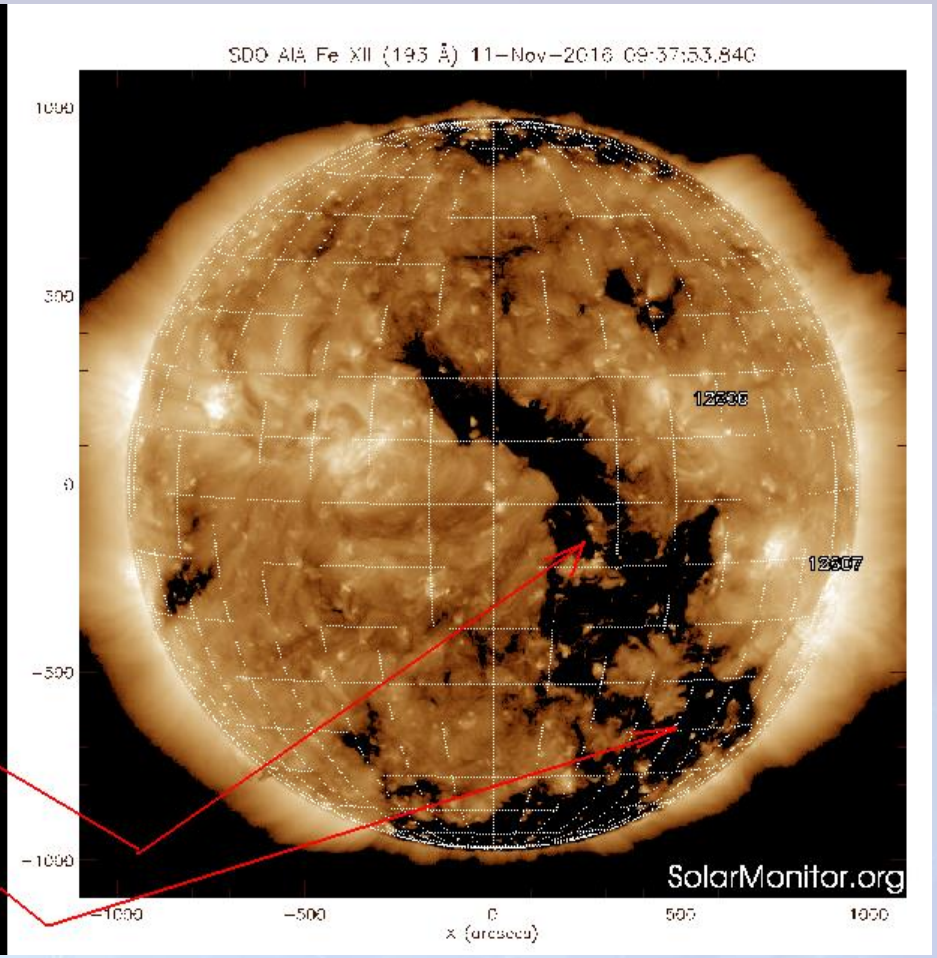
Averaged contrasts of big coronal holes (the reduction of coronal hole's brightness temperatures to quiet Sun ones) after VIRAC RT-32 observations on 2019-2020 (25th solar circle minimum) and on 2024-2025 (solar circle maximum)

D. Bezrukovs, POS, vol. 520, (BAASP 2025)002

The visibility of the extended coronal hole (“narrow coronal corridor”) in microwaves.
2016-11-11, VIRAC RT-32, Stokes I, 4.09 cm

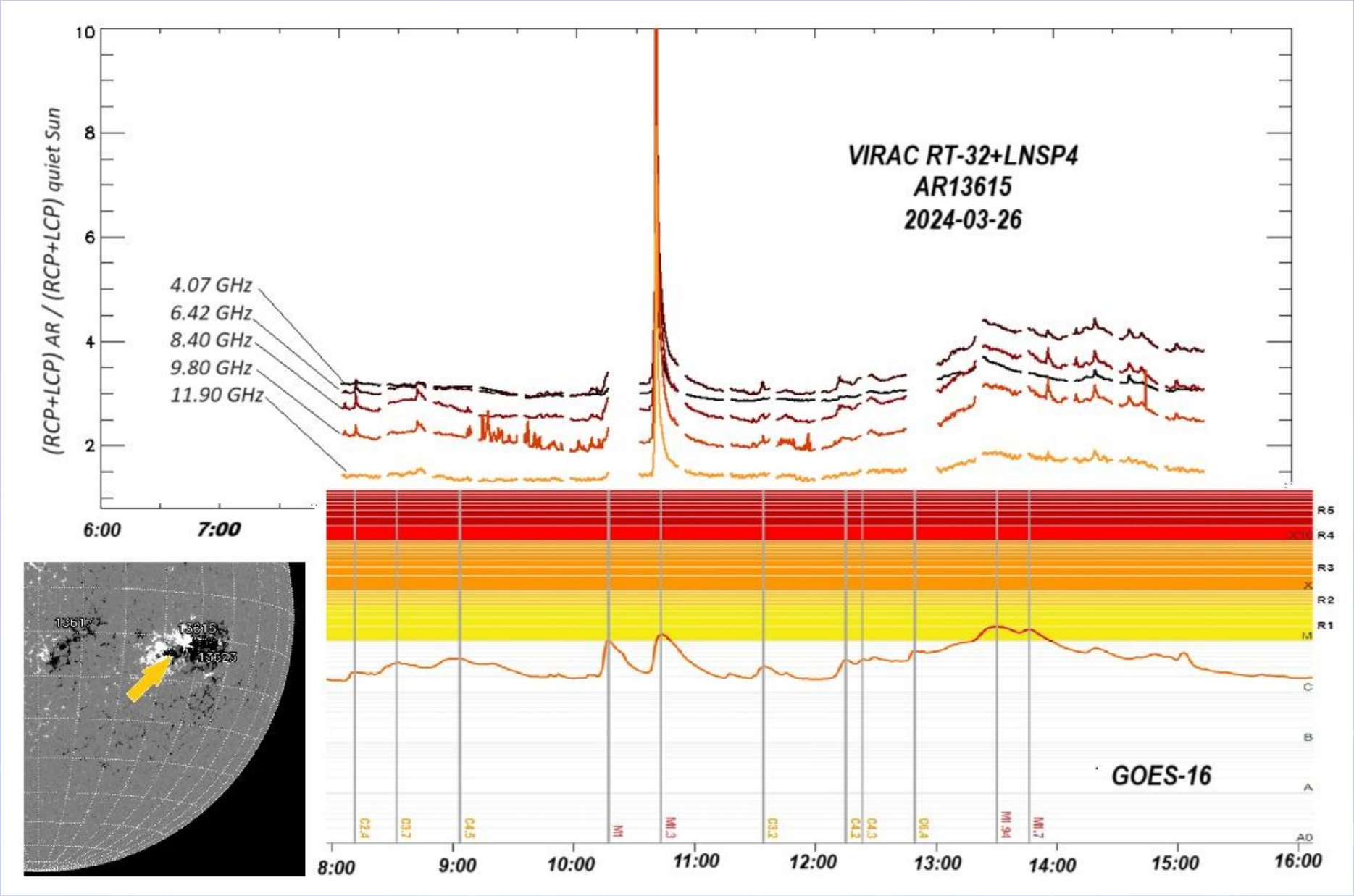


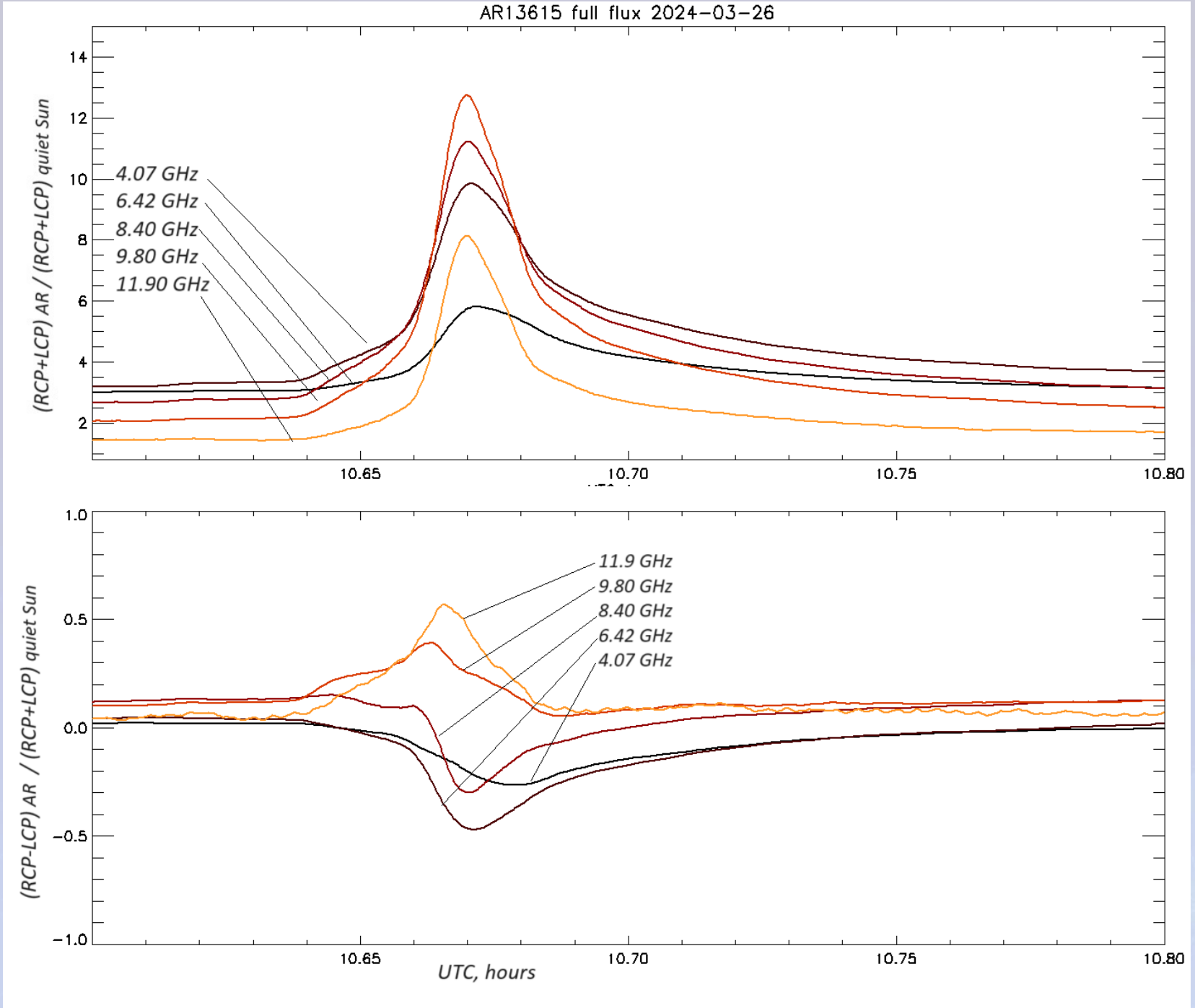
VIRAC RT-32 4.09cm
Increased contrast

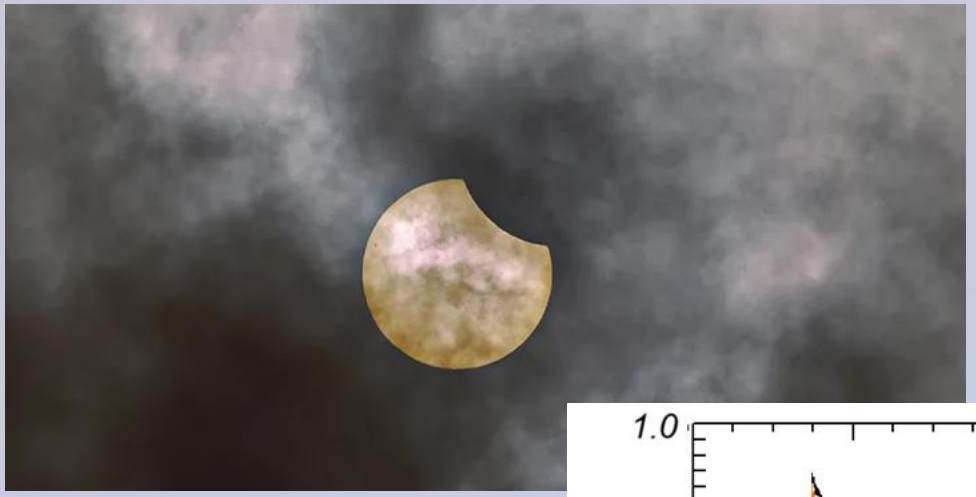


SDO AIA Fe XI

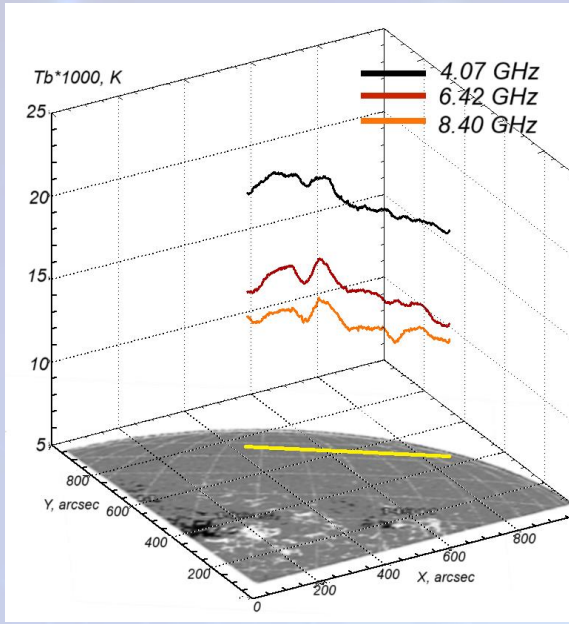
The long-term monitoring of the full microwave flux of AR 13615 on 2024-03-26

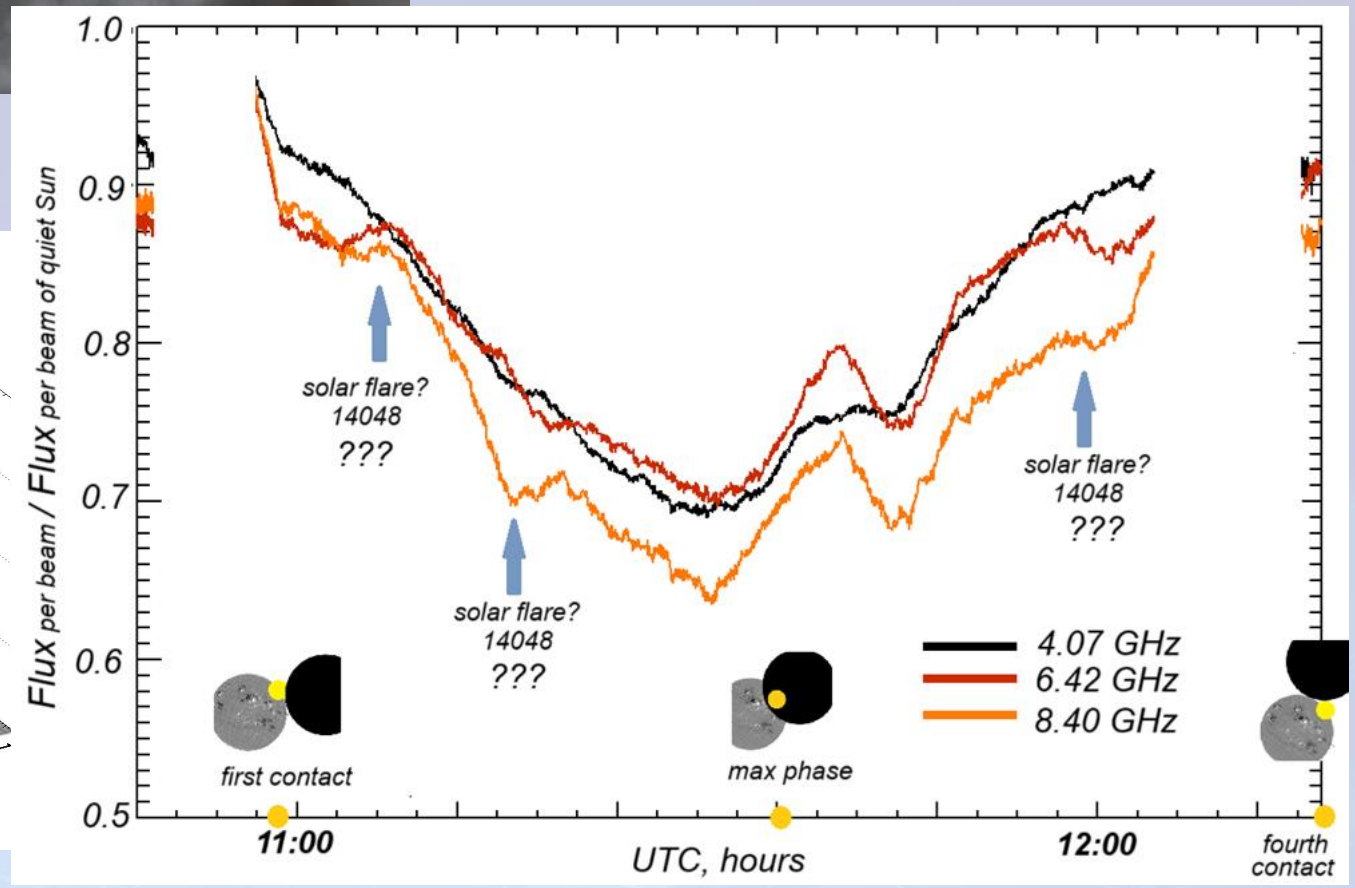



AR13615 full flux 2024-03-26
(RCP+LCP) AR / (RCP+LCP) quiet Sun
4.07 GHz
6.42 GHz
8.40 GHz
9.80 GHz
11.90 GHz
14
12
10
8
6
4
2
10.65
10.70
10.75
10.80
(RCP-LCP) AR / (RCP+LCP) quiet Sun
11.9 GHz
9.80 GHz
8.40 GHz
6.42 GHz
4.07 GHz
1.0
0.5
0.0
−0.5
−1.0
10.65
10.70
10.75
10.80
UTC, hours



The microwave spectral observation of the partial Sun eclipse on 2025, 29 March with VIRAC RT-32

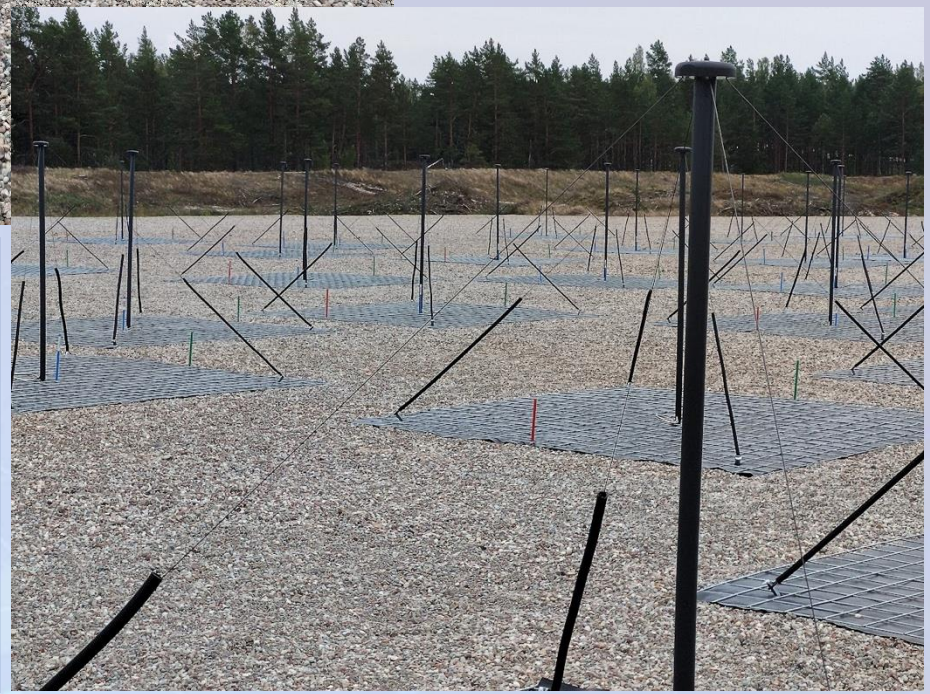




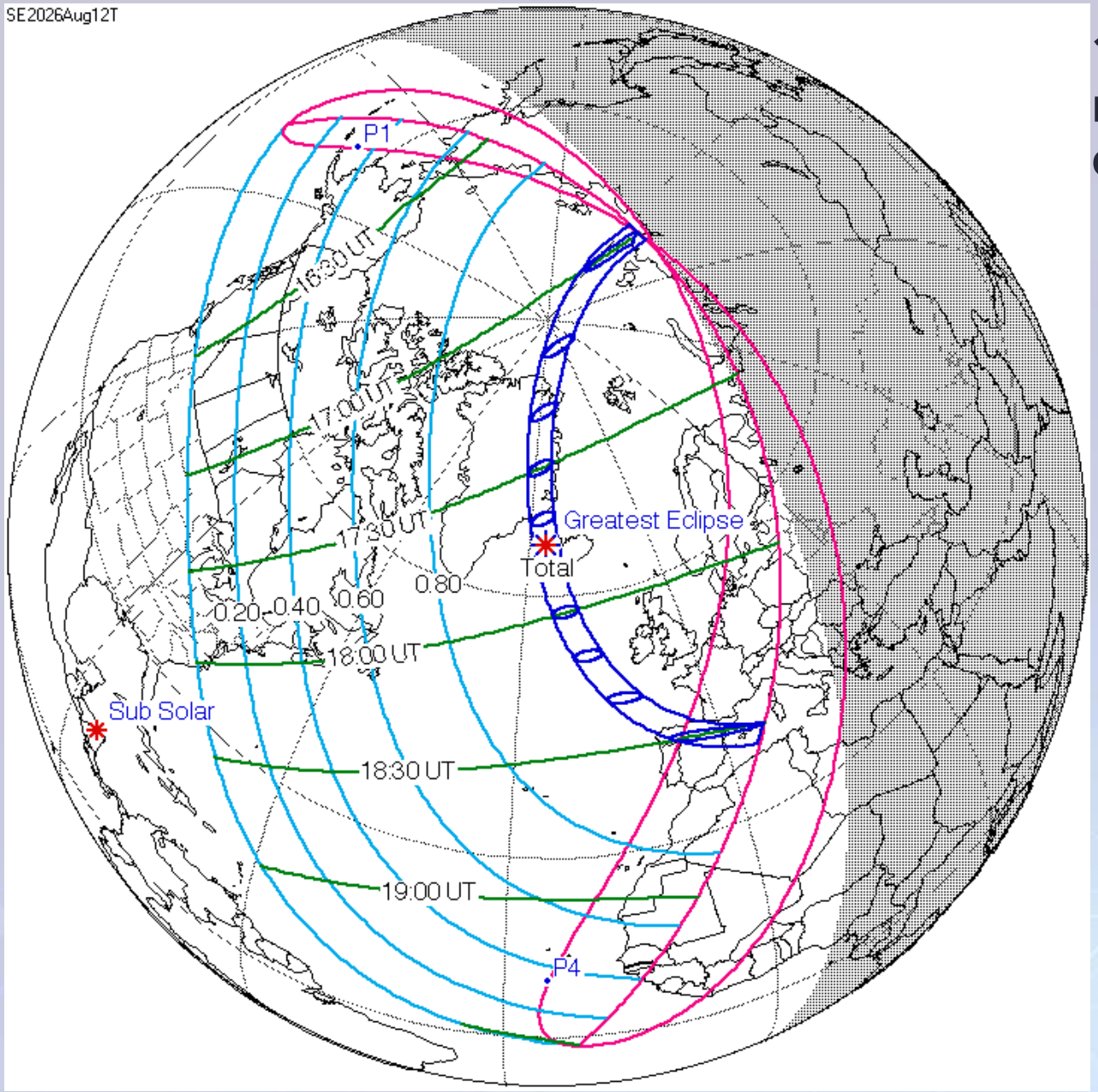




LOFAR LV614 LATVIA (Irbene)



The LOFAR LV614 station (Irbene, VIRAC) is the Latvian segment of the trans-European Very Long Baseline Interferometer (low - frequency). The radio antenna is physically divided into dipole LBA subarrays (10–90 MHz) and HBA tiles (110–250 MHz), implementing flexible multi-beam digital beamforming. In single station mode, it is used to study the Sun radio-bursts and ionospheric scintillations, in response to space weather events.

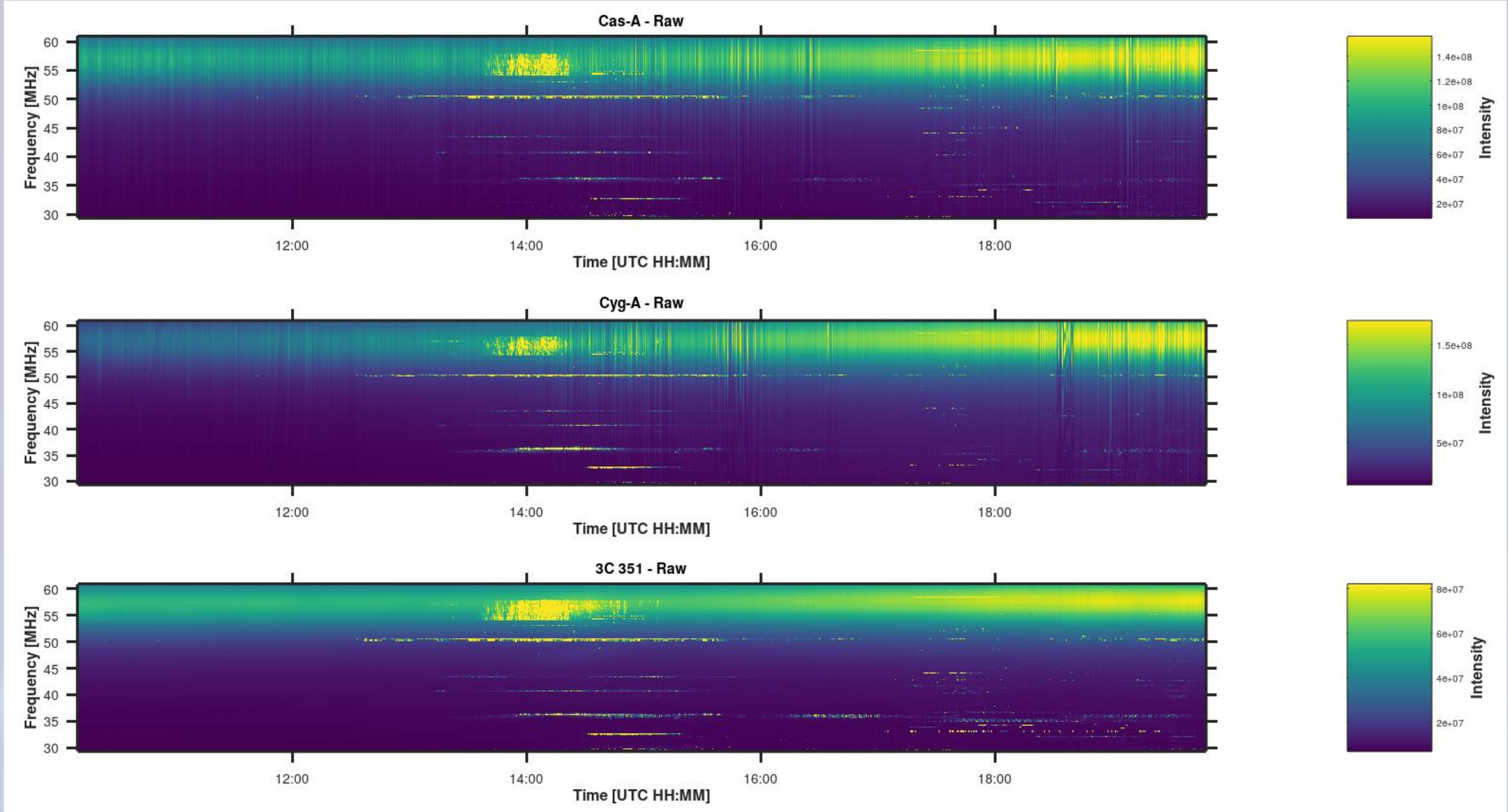


The path of the total solar eclipse on August 12, 2026, passed through five countries. The maximum width of the lunar shadow (umbra) on the Earth's surface was 294 kilometers.

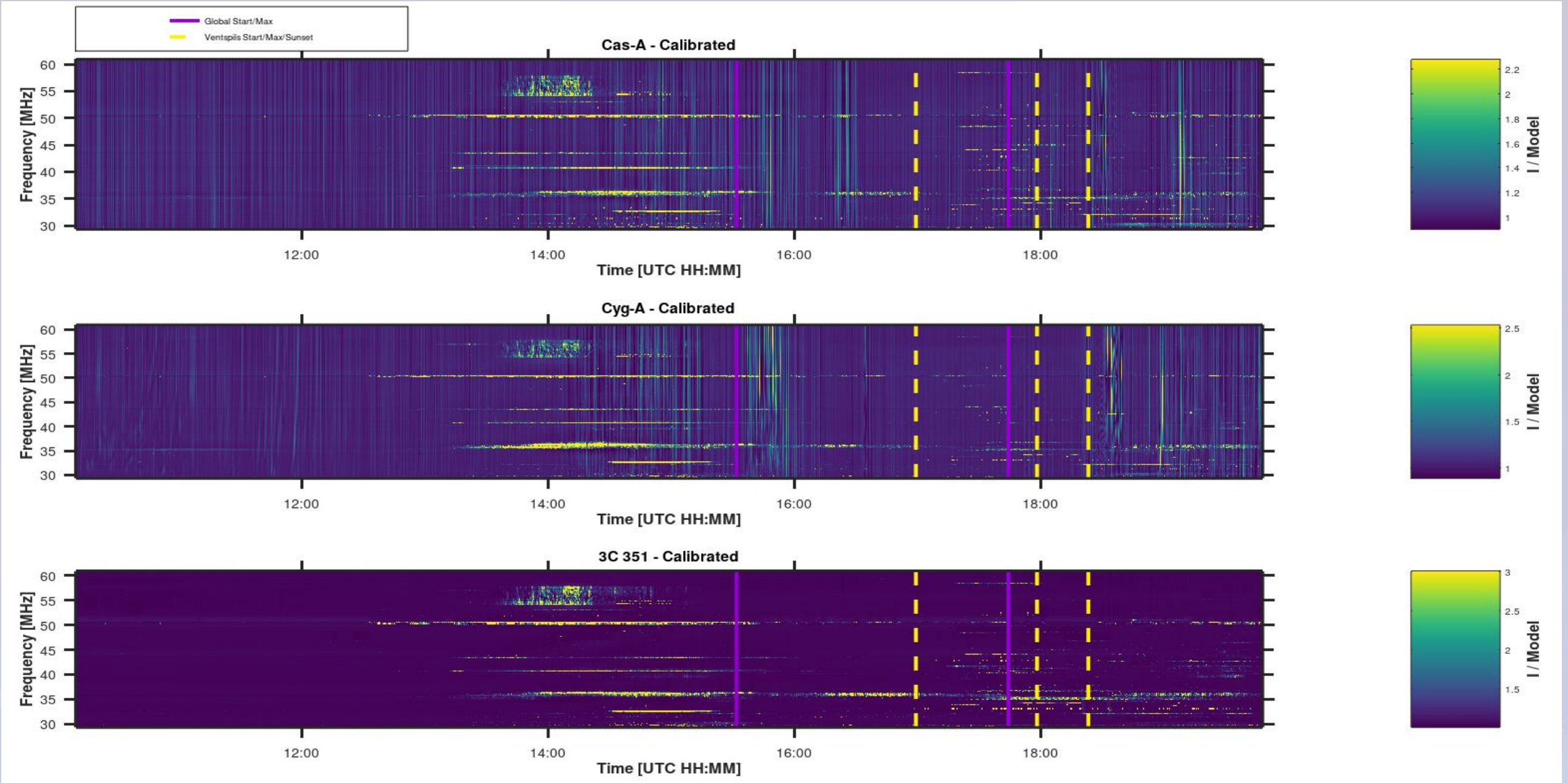
The path of totality affected the following regions:
Greenland: The path crossed the desolate ice fields and fjords along the island's eastern coast.
Iceland: The eclipse covered the western part of the country, including the capital, Reykjavik. The point of longest totality was located in the ocean, off the west coast of Iceland.
Spain: A broad umbra passed across the northern and central regions of mainland Spain (from the Atlantic coast to the Mediterranean), and at sunset it covered the Balearic Islands.
Portugal: Totality was only visible in a tiny area in the far northeast of the country, near the border with Spain.



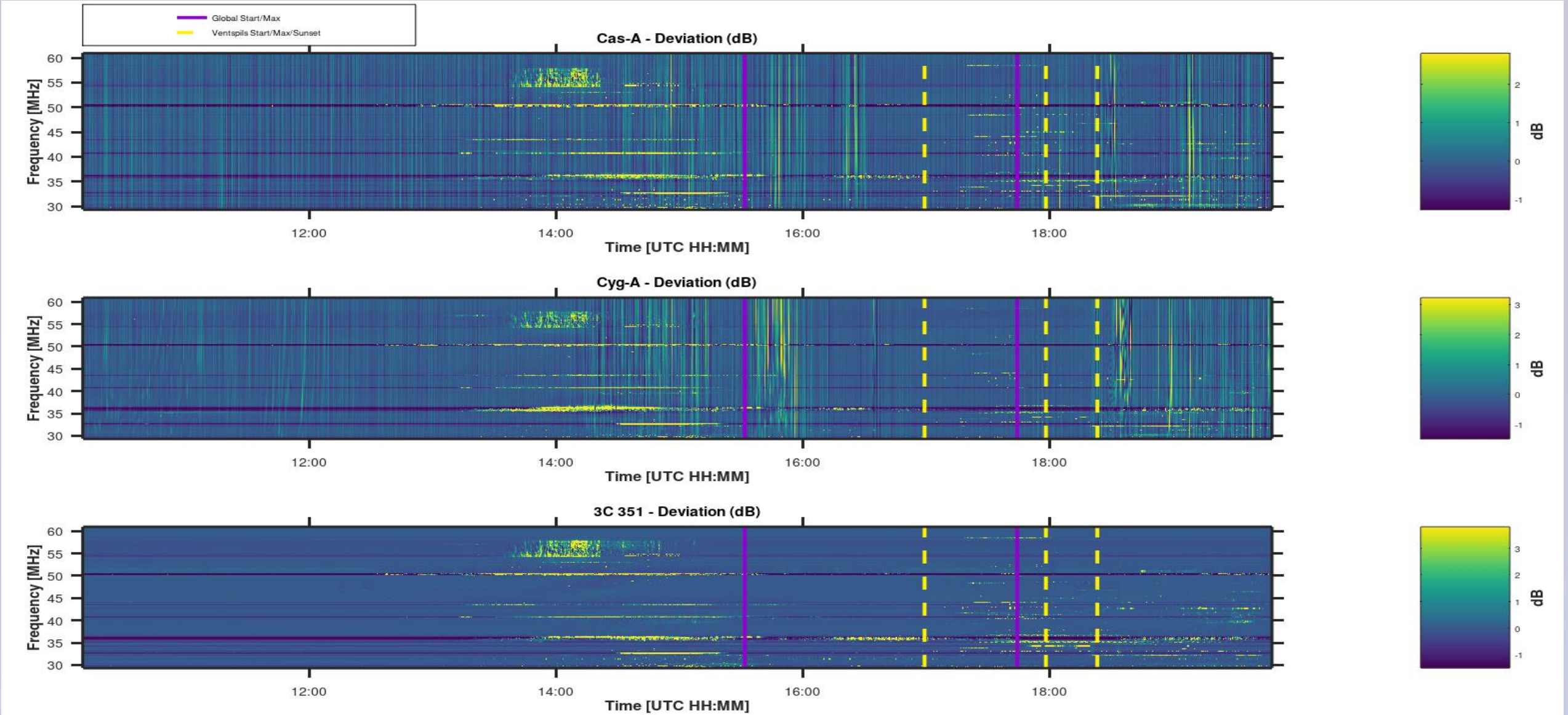
August 12, 2026 — Total Solar Eclipse over Bardenas Reales de Navarra, Spain



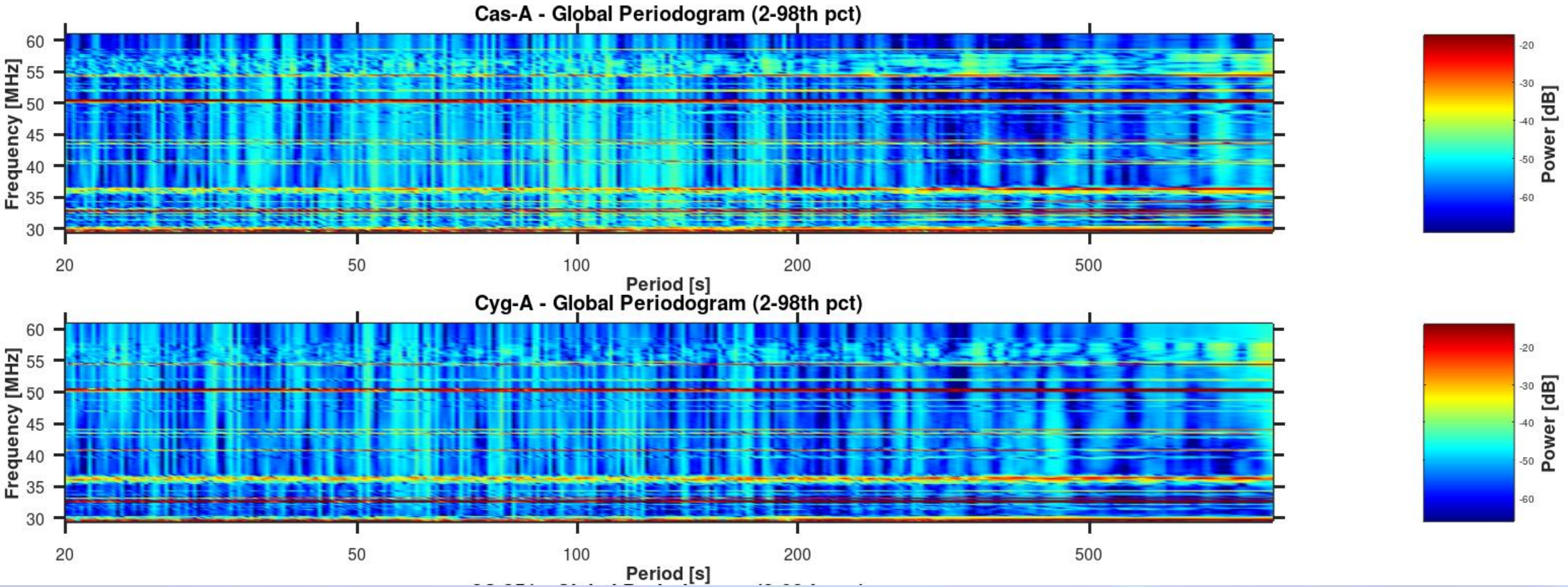
LOFAR LV614, LBA 30 MHz bandwidth, three beams to radio sources Cas-A, Cyg-A, 3C351 (weak quasar), 162 frequency channels per source. Bandpass hill and strong RFI clearly visible.



Dynamic spectrum after removing the “hill” in the signal, using a "checkered" spline calibration surface. Vertical lines – time windows of solar eclipse, local (yellow) and global (start and maximum).



The map shows not the absolute amplitude level, but the deviation from each channel's own typical level in dB. This removes the difference in base sensitivity between channels and makes visible only relative, short-term fluctuations (scintillations, RFI bursts), better than the static shape of the frequency response band.



"Global" periodogram for radio sources Cas-A and Cyg-A (spectrum converted to periods of variations instead of time). It is evident here that on the day of the solar eclipse on August 12, 2026, weak quasi-periodic variations were present in the dynamic spectra in the period band of 20–900 sec, most pronounced in the range of 50–200 sec. It is also evident that the periodograms look completely different; the quasi-periods of Cas-A and Cyg-A are generally different. This is reasonable since the angular separation between radio sources Cassiopeia A (Cas-A) and Cygnus A (Cyg-A) is 36.365 deg. (or 36° 21'53'').

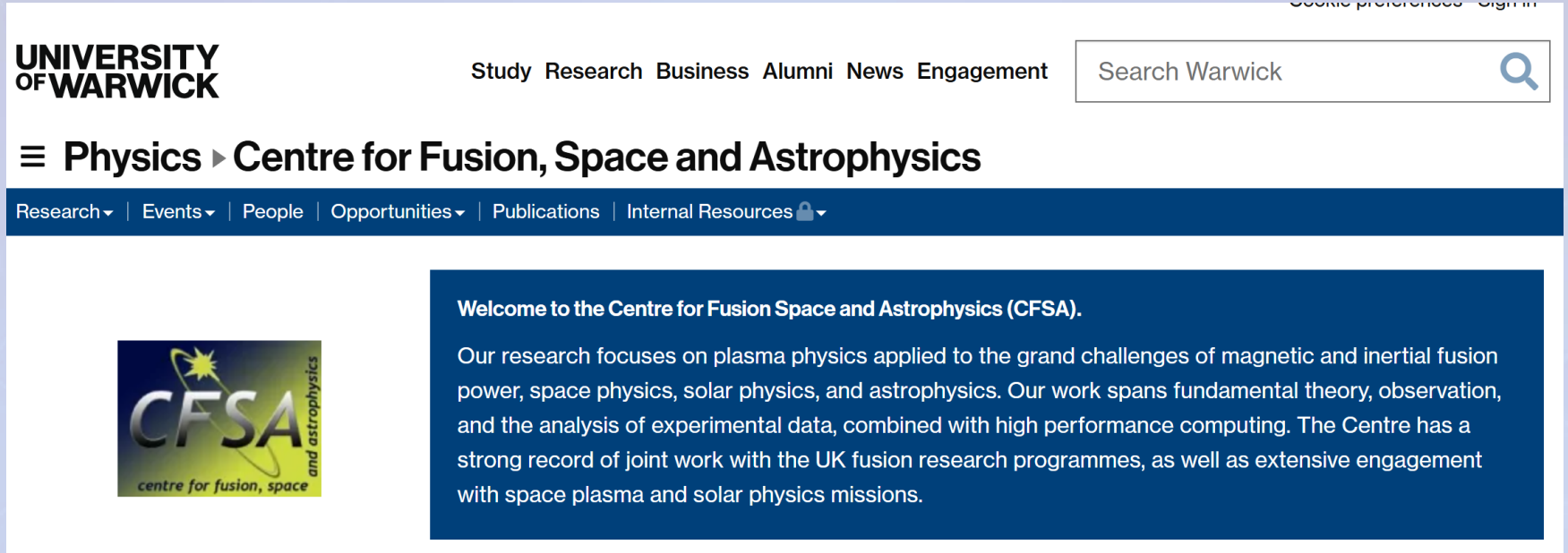
Multi-Wavelength Study of Quasi-Periodic Pulsations in Solar and Stellar Flares (STEF)

Principal Investigator: Prof. Valery Nakariakov (Warwick University)
Co-Principal Investigator: Dr. Dmitrii Kolotkov (Warwick University)
Funded by: Latvian Science Council, Fundamental and Applied Research Projects
Project's duration: 01.01.2023. – 31.12.2025.
Project's No: lzp-2022/1-0017

Partner:

- **Centre for Fusion, Space and Astrophysics (CFSA),** Department of Physics, University of Warwick, Coventry, United Kingdom

Team:
Bezrukovs, V. Nakariakov, D. Bezrukovs, J. Šteibergs, A. Aberfelds, A. Dzelme, K.Veitners, A. Kalniņa



FLPP FUNDAMENTAL AND APPLIED RESEARCH PROJECTS

VENTSPILS AUGSTSKOLA

STEF

VIRAC

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Article

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Polarisation of decayless kink oscillations of solar coronal loops

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Check for updates

Sihui Zhong[1], Valery M. Nakariakov[1,2] ✉, Dmitrii Y. Kolotkov[1,3], Lakshmi Pradeep Chitta[4], Patrick Antolin[5], Cis Verbeeck[6] & David Berghmans[6]

Decayless kink oscillations of plasma loops in the solar corona may contain an answer to the enigmatic problem of solar and stellar coronal heating. The polarisation of the oscillations gives us a unique information about their

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Astronomy & Astrophysics

LETTER TO THE EDITOR

Undersampling effects on observed periods of coronal oscillations

Daye Lim[1,2,⋆], Tom Van Doorsselaere[1], Valery M. Nakariakov[3,4], Dmitrii Y. Kolotkov[3,4], Yuhang Gao[5,1], and David Berghmans[2]

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Sciences, Ventspils LV-3601, L
[5] School of Earth and Space Sci

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Microwave Observations of the Sun in Virac: An Experience of the Implementation

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Accepted: 17 March 2023

polarimetric observations of the Sun still remain one of t
ar physics and the space weather creation. Taking into accou
of microwave emissions in plasma these solar observatio
or direct measurements of plasma parameters and magne
e and lower corona. The analysis of spectra of the polarized so
distribution of plasma parameters and inductions of coror
nge of heights above the photosphere.
ational Radio Astronomy Centre (VIRAC), Latvia has a possibi
hannel spectral polarimetric observations of the Sun in the 2.
T-32 radio telescope in "single dish" regime. This paper reports
nethodical issues of the implementation of these observatio
solar physics, and studies of the space weather that could
of interest are discussed as well.

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dio astronomy, space weather

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Advance Access publication 2023 August 31

Comparison of damping models for kink oscillations of coronal loops

Yu Zhong,[1] Dmitrii Y. Kolotkov[1,2] Sihui Zhong[1] and Valery M. Nakariakov[1,3⋆]

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[3] Centro de Investigacion en Ast

Accepted 2023 August 21. in o

ABSTRACT

Kink oscillations of solar
corona. The accurate me
as the transverse density
rapidly decaying kink osc
Gaussian and exponential
theoretically that the tran
damping model. In this v
Carlo Bayesian approach
that in 7 out of 10 analyse
damping is exponential,
damping model. The pos
number of events, especi
period and amplitude, an

Key words: waves – Su

1 INTRODUCTION

Kink oscillations of plasma
corona are among the most
atmosphere (e.g. Nakariako

The outermost, fully-ionised an
atmosphere of the Sun, the c
birthplace of extreme events c
coronal mass ejections[1]. The
laboratory allowing for high-re
which are of interest for var
laboratory plasma physics appli
enigmatic puzzles, such as the
and heating of the plasma to
magnitude higher than the su
rapidly developing avenues of
magnetohydrodynamic (MHD)
Coronal waves are of specific i
heating, see, e.g., ref. 3, seismo
structures e.g., refs. 4–7, and ar
releases, e.g., ref. 8. A ubiquitous

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galaxies

MDPI

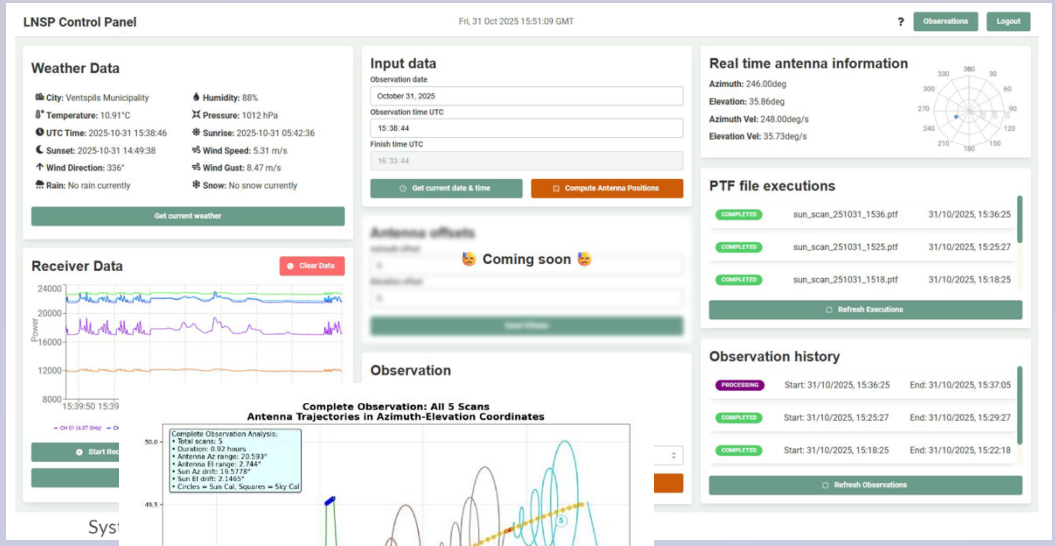
Article

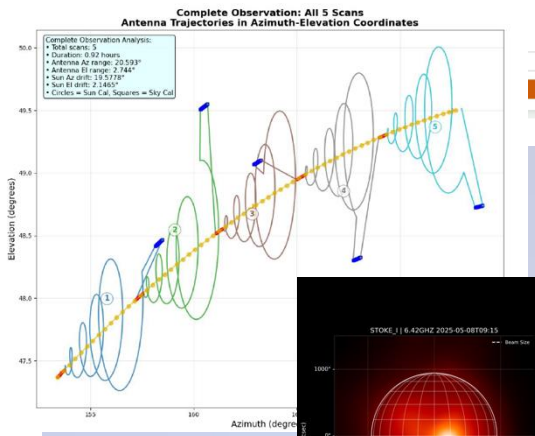
Effects of the intraday variability of the radio galaxy Perseus A (3C 84) at the frequency 6.5 GHz and evidence for a possible FRB event

Vladislavs Bezrukovs[1,*], Oleg Ulyanov[2], Artem Sukharev[1,2], Vyacheslav Zakharenko[2], Mikhail Ryabov[2], Viktor Ozhinskyi[3], Volodymyr Vlasenko[3], Anatolyi Poikhalo[3], Oleksandr Konovalenko[2], Eugene Alekseev[4], Mykhailo Palamar[5], Viktor Voityuk[3], Vladyslav Chmil[6], Dmytro Bakun[3], Daniil Zabora[2], Ivar Shmeld[1], Marina Konuhova[1,7,*]

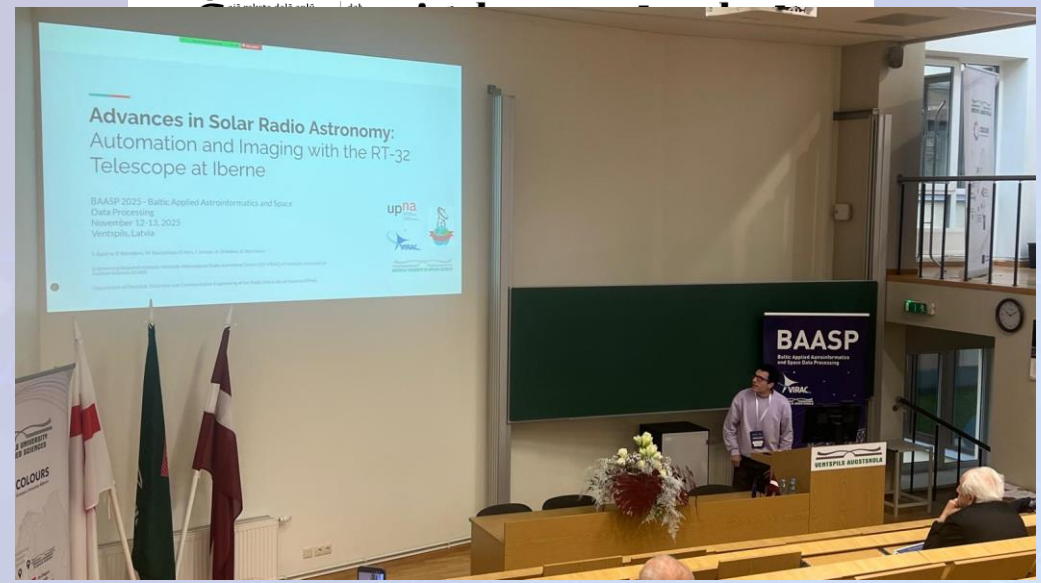

Zvaigžņotā
2025/2026 ZIEMA
DEBESS
Latvijā JAUNA
skolas observatorija

Zvaigžņotā
2025 RUDENS
DEBESS
ANTIMATĒRIJAS
melnie caurumi
EINŠTEINAM
būs "savs"


LNSP Control Panel
Fri, 31 Oct 2025 15:51:09 GMT
Observations
Logout
Weather Data
City: Ventspils Municipality
Humidity: 88%
Temperature: 10.91°C
Pressure: 1012 hPa
UTC Time: 2025-10-31 15:38:46
Sunrise: 2025-10-31 05:42:36
Sunset: 2025-10-31 14:49:38
Wind Speed: 5.31 m/s
Wind Direction: 336°
Wind Gust: 8.47 m/s
Rain: No rain currently
Snow: No snow currently
Get current weather
Input data
Observation date
October 31, 2025
Observation time UTC
15:38:44
Finish time UTC
16:33:44
Get current date & time
Compute Antenna Positions
Real time antenna information
Azimuth: 246.00deg
Elevation: 35.86deg
Azimuth Vel: 248.00deg/s
Elevation Vel: 35.73deg/s
PTF file executions
COMPLETED
sun_scan_251031_1536.ptf
31/10/2025, 15:36:25
sun_scan_251031_1525.ptf
31/10/2025, 15:25:27
sun_scan_251031_1518.ptf
31/10/2025, 15:18:25
Refresh Executions
Receiver Data
Clear Data
Coming soon
Observation
Observation history
PROCESSING
Start: 31/10/2025, 15:36:25
End: 31/10/2025, 15:37:05
Start: 31/10/2025, 15:25:27
End: 31/10/2025, 15:29:27
Start: 31/10/2025, 15:18:25
End: 31/10/2025, 15:22:18
Refresh Observations


Complete Observation: All 5 Scans
Antenna Trajectories in Azimuth-Elevation Coordinates
Elevation (degrees)
Azimuth (degrees)


INTERESANTI
ARTJOMS SUHAREVS,
VLADISLAVS BEZRUKOVS
Kosmiskie laikapstākļi.
Saules aktivitātes
uz m
SAULES SISTĒMA
PROCESI UZ SAULES CAUR
AKTIVITĀTES ENERĢIJU
MŪSU PLANĒTAS ATMO


Advances in Solar Radio Astronomy:
Automation and Imaging with the RT-32
Telescope at Iberne
BAASP
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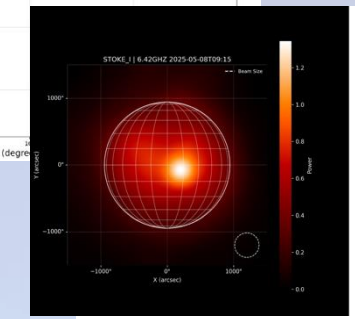
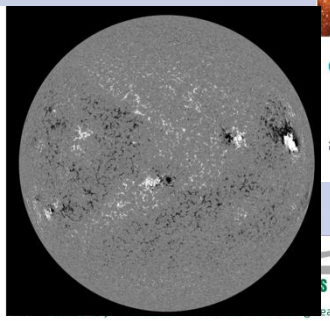

STOKE_I | 6.42GHZ 2025-05-08T09:15




June 2-6, 2025
PRIMORSKO, BULGARIA
workshop

JUNE 3-7, 2024
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INITIAVE FOR SPACE
WEATHER INVESTIGATIONS
WORKSHOP
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Mikroviļņu Saules novērojumi STEF projekta ietvatos
Scientific workshop on microwave solar observations at the VSRC STEF project
May 15, 2024

Novel proxies and approaches for solar flare forecasting (FLARE)

Principal Investigator: Dr. Dmitrii Kolotkov (Warwick University)
Funded by: Latvian Science Council, Fundamental and Applied Research Projects
Project's duration: 01.01.2025. – 31.12.2027.
Project's No: lzp-2024/1-0023

Partners:

- **Centre for Fusion, Space and Astrophysics (CFSA),** Department of Physics, University of Warwick, Coventry, United Kingdom
- **Centre for mathematical Plasma Astrophysics,** Department of Mathematics, Leuven, Belgium;

Team:
V. Bezrukovs, V. Nakariakov, D. Bezrukovs, S. Zhong, S.Belov, N.Jotkus, A.Kalnina, M. Purviņš

Planed results:

- Scientific articles published in the Q1 or Q2 7
- Other scientific articles 2
- Scientific databases 2
- Other new product or technology 1
- 3 public lectures, 3 interviews,
- 3 science-popular articles and 12 reports in the conferences;

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FLPP FUNDAMENTAL AND APPLIED RESEARCH PROJECTS

FLARE

VIRAC

Characterisation of Extreme Space Weather Effects on the Ionosphere (IONEX)

Principal Investigator: Prof. Ilja Usoskin (Sodankylä Geophysical Observatory of OULU University, Finland.

Funded by: Latvian Science Council, Fundamental and Applied Research Projects
Project's duration: 01.01.2026. – 31.12.2028.
Project's No: lzp-2025/1-0067

Project Partners:

- **Sodankylä Geophysical Observatory** of OULU University, Finland.
- **Institute of Radio Astronomy of the National Academy of Sciences of Ukraine** (IRA NASU), Kharkiv, Ukraine
- **Odesa Radio Astronomy Observatory "URAN-4",** Institute of Radio Astronomy of the National Academy of Sciences of Ukraine (IRA NASU), Odesa, Ukraine
- **Institute of Geophysics** of the National Academy of Sciences of Ukraine, Ukraine
- **Faculty of Mathematics,** Physics and Information Technologies of Odesa I. I. Mechnikov National University

Team:

V. Bezrukovs, M. Ryabov, M. Orlyuk, D. Zabora, E.Strakhov, D.Zhykul, Y. Khromov, V.Dubovenko, O.Shimbareva & A. Sukharev

Planed results:

- Scientific articles published in the Q1 or Q2 3
- Other scientific articles 3
- Scientific databases 2
- Other new product or technology 1
- 3 public lectures, 3 interviews,
- 3 science-popular articles and 6 reports in the conferences;

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FLPP FUNDAMENTAL AND APPLIED RESEARCH PROJECTS

Latvian Council of Science

VIRAC

Research on Space Weather During Solar Cycle 25 Observed Along the Struve Geodetic Arc (SANTA)

Principal Investigator: Dr. Artem Sukharev, Institute of Radio Astronomy, National Academy of Sciences of Ukraine, Ukraine

Funded by: Latvian Science Council, Fundamental and Applied Research Projects

Project's duration: 01.04.2025 – 31.03.2028

Project's No: 1.1.1.9/LZP/1/24/048

Project Partners:

- **Space Radio-Diagnostics Research Center**, University of Warmia and Mazury, Poland.
- Space Research and Technology Institute of the Bulgarian Academy of Sciences.
- **Sodankylä Geophysical Observatory** of OULU University, Finland.
- **Institute of Radio Astronomy of the National Academy of Sciences of Ukraine** (IRA NASU), Kharkiv, Ukraine
- **Odesa Radio Astronomy Observatory "URAN-4",** Institute of Radio Astronomy of the National Academy of Sciences of Ukraine (IRA NASU), Odesa, Ukraine

PostDoc Latvia

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NACIONĀLAIS ATTĪSTĪBAS PLĀNS 2020

EIROPAS SAVIENĪBA Eiropas Reģionālās attīstības fonds

IEGULDĪJUMS TAVĀ NĀKOTNĒ

VIRAC



Thank you!

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Thank you for your attention! Questions?

FLARE
"Novel proxies and approaches for solar flare forecasting"
Latvian Council of Science
project Nr. lzp-2024/1-0023

Latvijas Zinātnes padome

FLPP
FUNDAMENTAL AND APPLIED RESEARCH PROJECTS



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