The Sun, Space Weather and Geosphere
UN/Azerbaijan Workshop on the International Space Weather Initiative

Microwave observations of the Sun with VIRAC RT-32 Radio Telescope

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Ventspils University of Applied Sciences
Engineering Research Institute
“Ventspils International Radio Astronomy Centre”
(VIRAC)

RT-32

RT-16

LOFAR

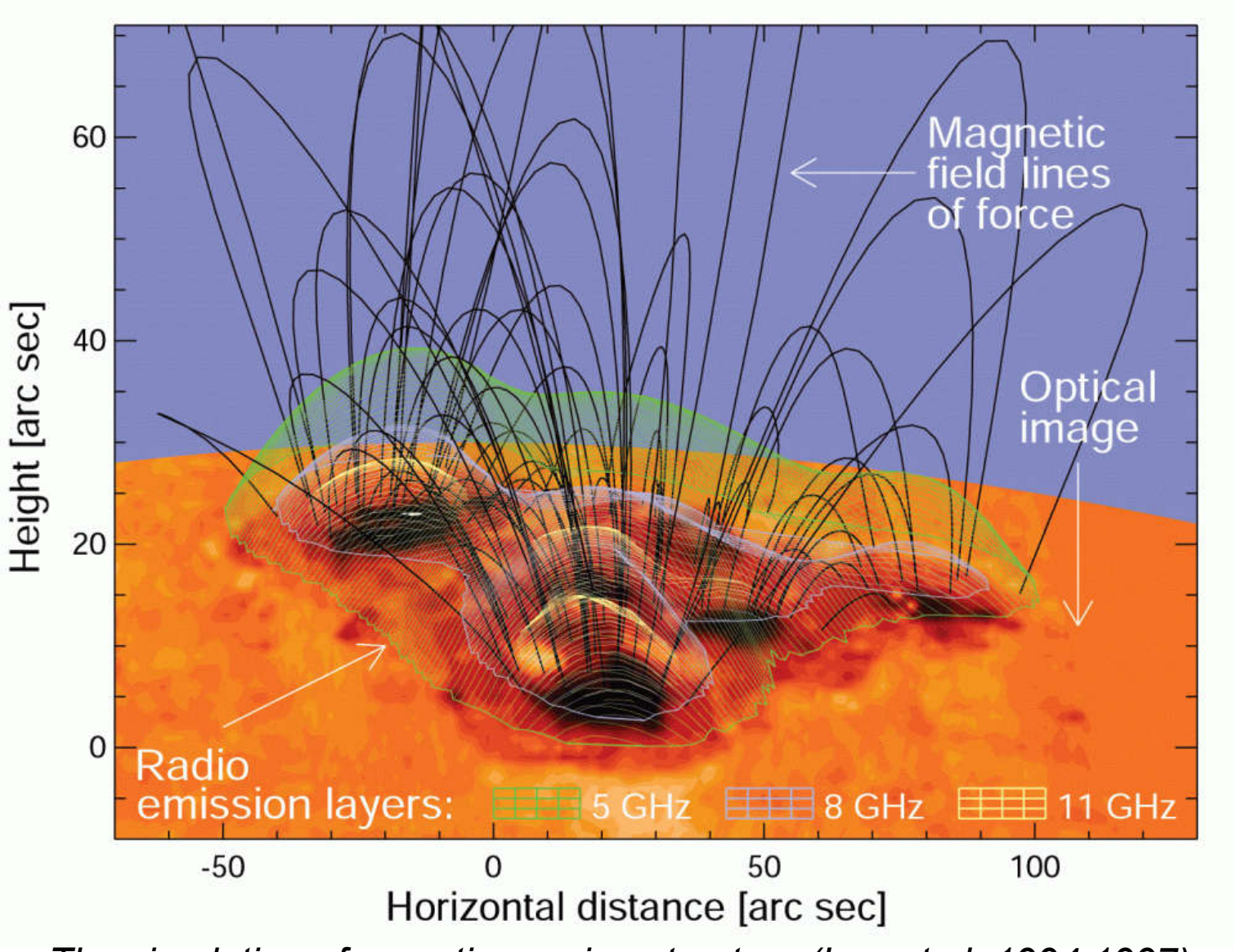
Main areas of the ERI VIRAC activities:

- Astronomy and Astrophysics
- High Performance Computing
- Remote Sensing and Satellite Engineering

- *VLBI Activity*
- *LOFAR Activity*
- *Interstellar Dust Processes*
- *Space Masers Observations*
- *Active Nuclears of Galaxies*
- *Solar Microwave Observations and Solar Physics*

ERI VIRAC is:

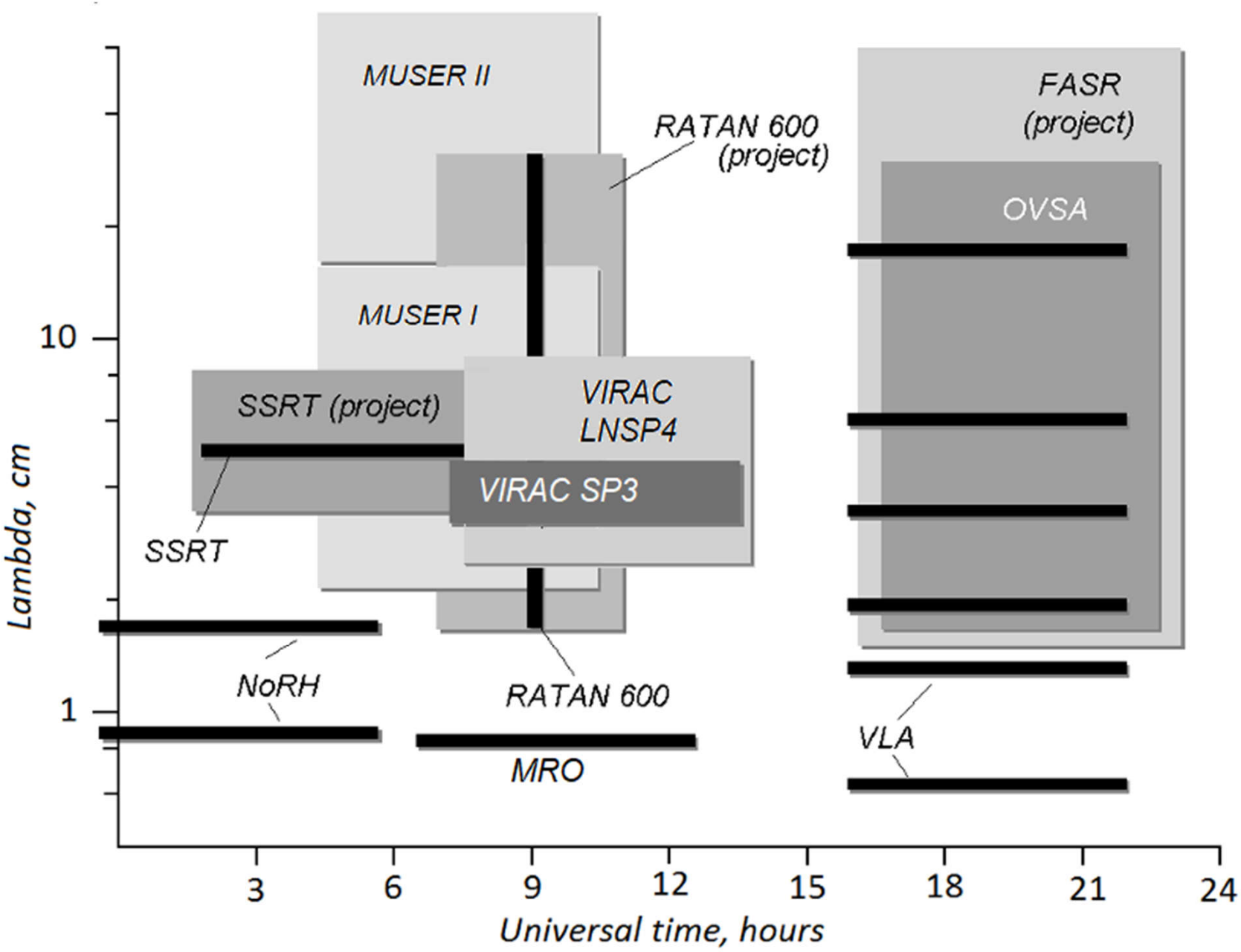
Full member of EVN
Member of JIV-ERIC
Observer of International LOFAR Telescope Network



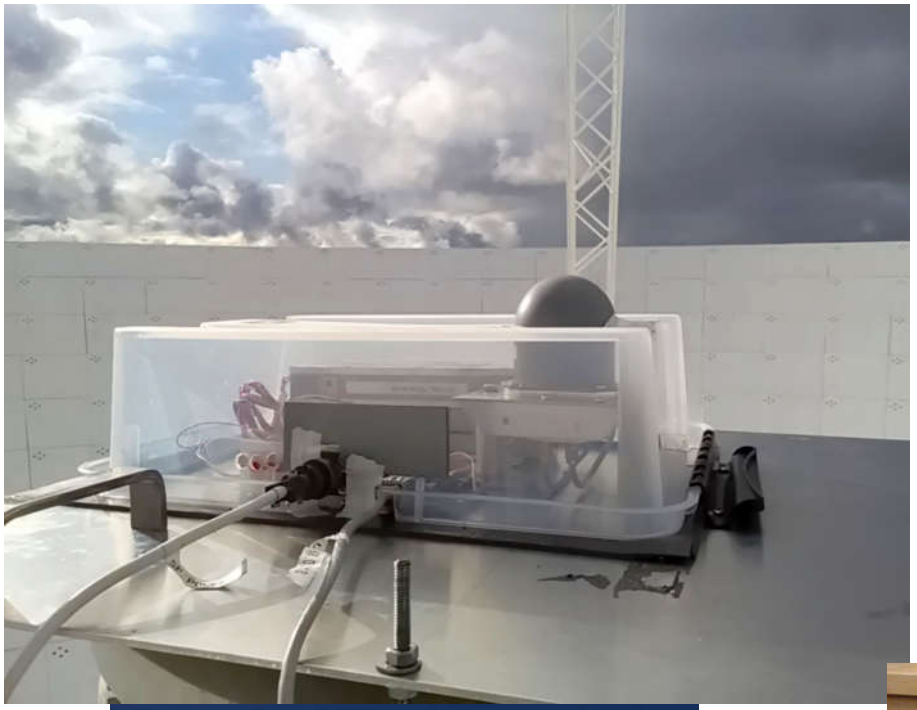
The simulation of an active region structure (Lee et al. 1994,1997)

Taking into account that the microwave emission for 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 by well-known methods

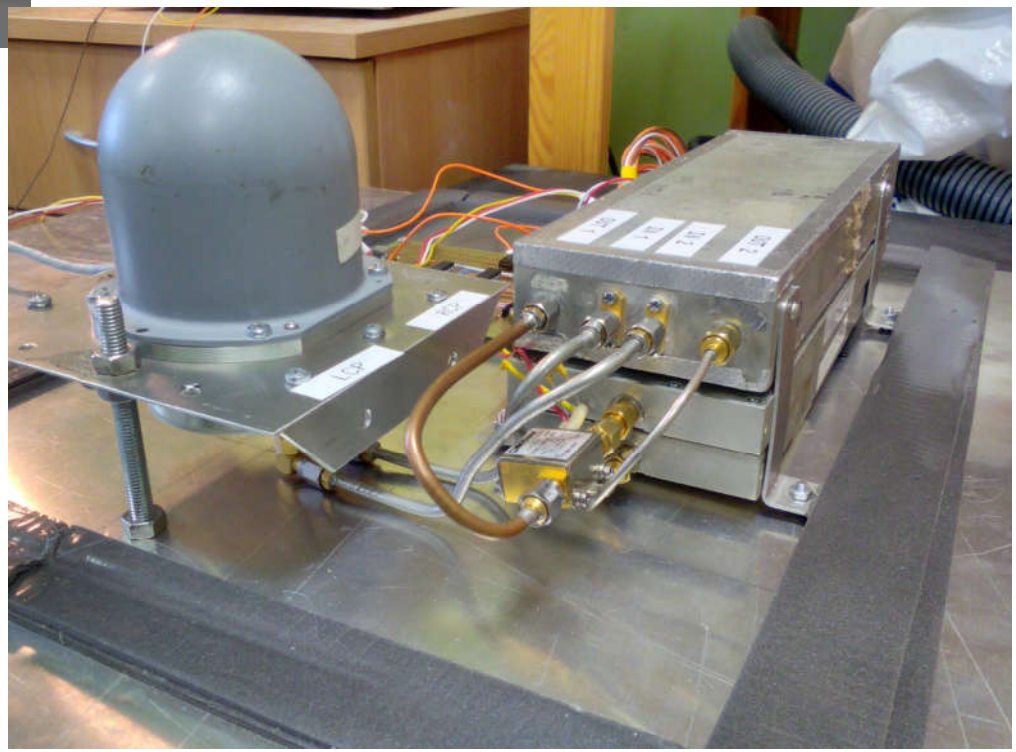
The time-wavelength chart of some "Sun dedicated" instruments



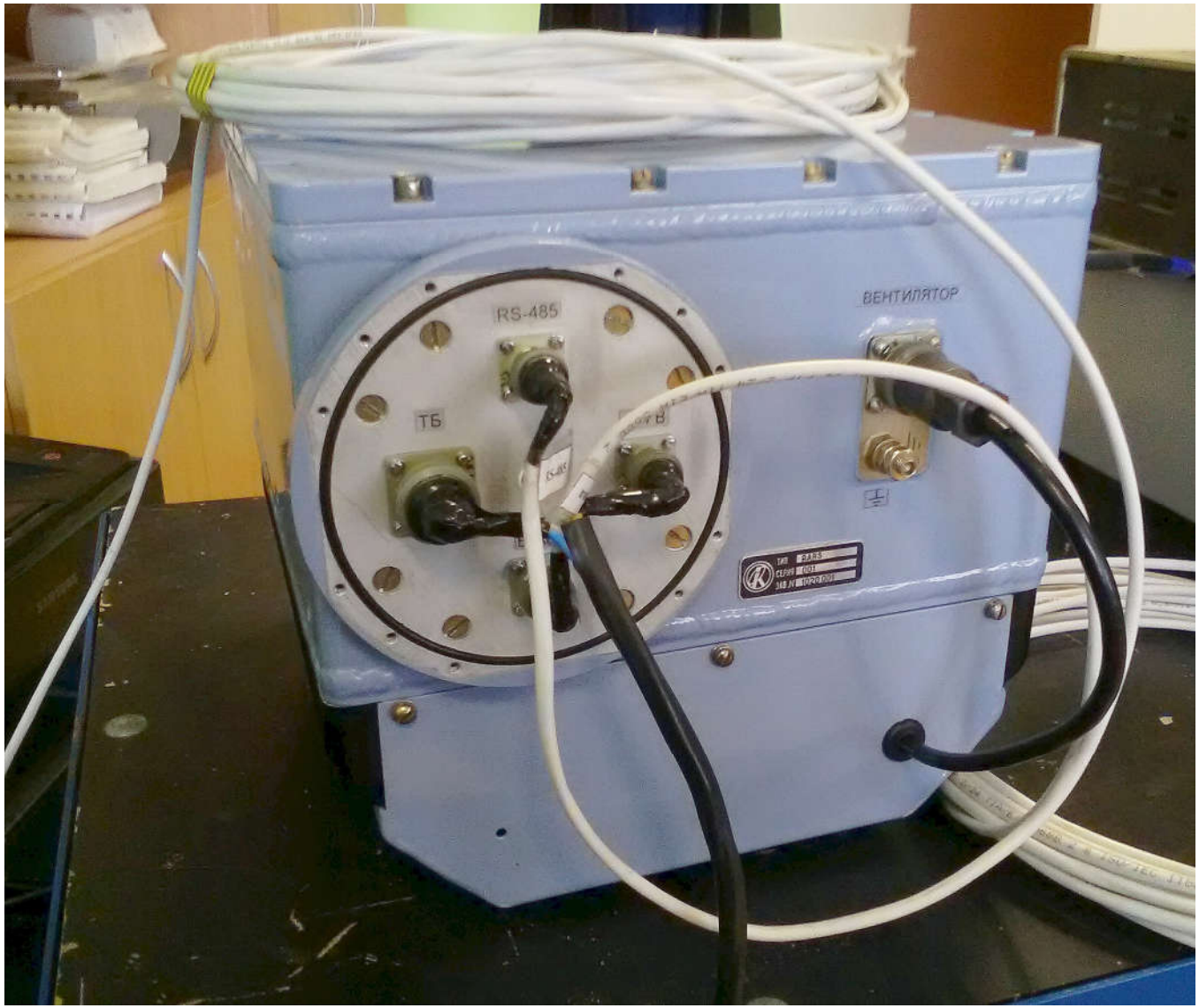
Multichannel solar spectral polarimeter VIRAC SP3

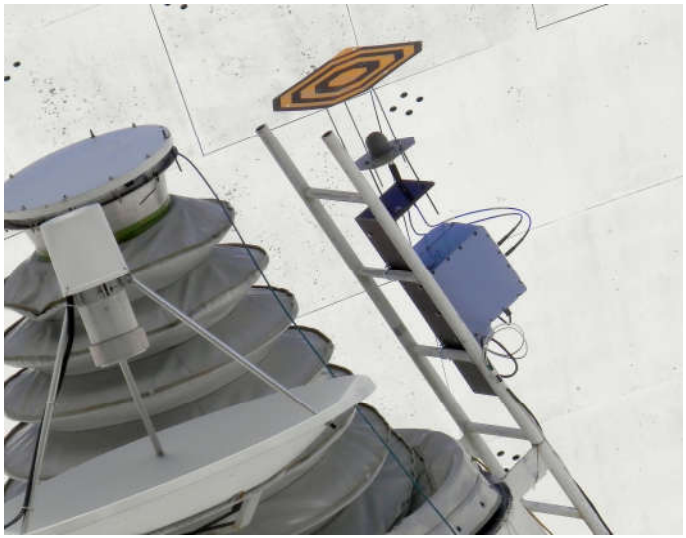


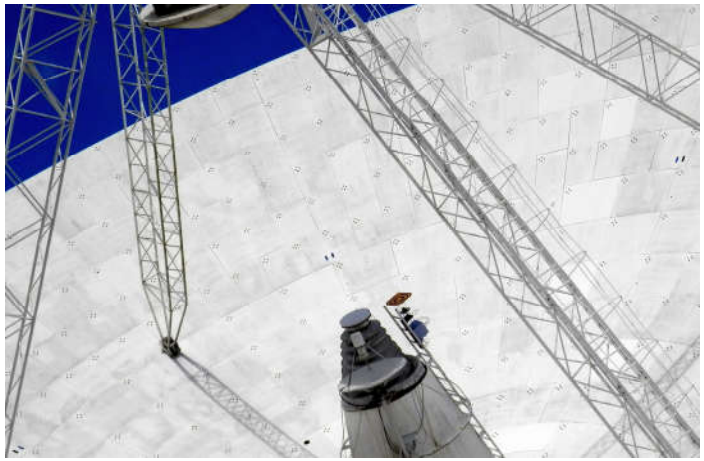
- frequency range 6.3 – 9.4 GHz (3.2-4.7 cm)
- 16 frequency channels
- LCP and RCP
- S/N ratio > 16...18 db
- dynamic range 20...22 db
- band width 80 MHz
- antenna HPBW 5.2 - 3.5 arc. min
- sampling rate up to 50 sample /sec
- 16 bit ADC



The new Low Noise Spectral Polarimeter LNSP4 for 2.1-7.5 cm under tests in the laboratory and onto the RT-32 radio telescope





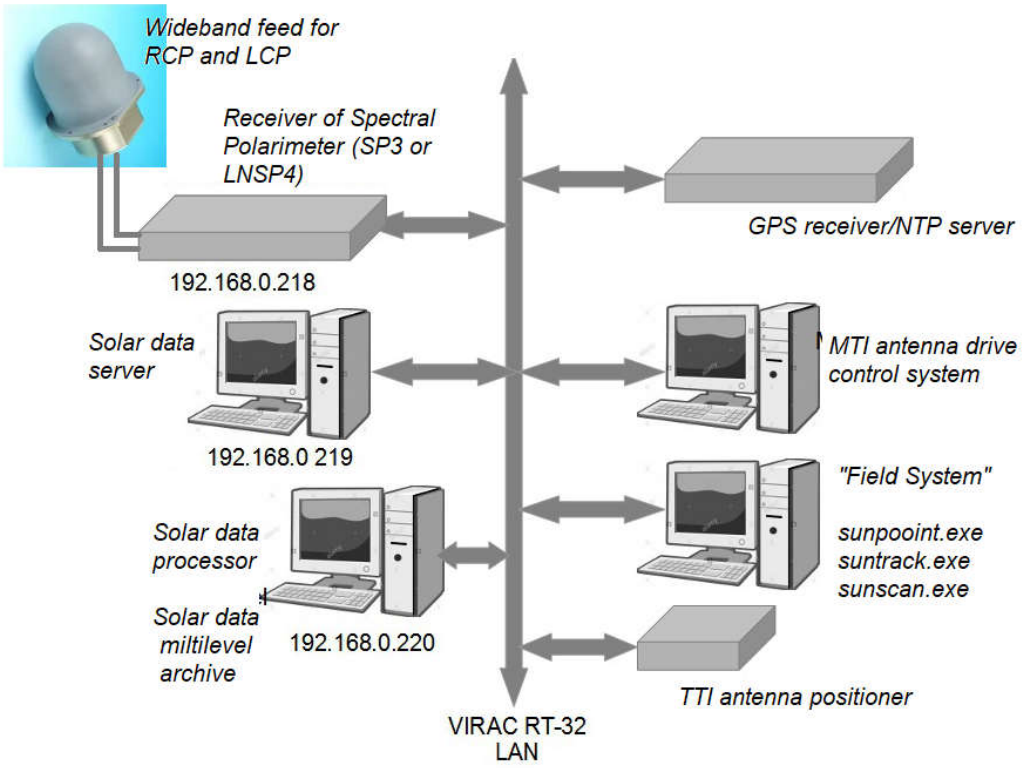


Solar spectral polarimeters VIRAC SP3 vs LNSP4

	SP3	LNSP4
Frequency range	6.3 – 9.3 GHz	4.1 – 14.2 GHz
Number of channels	16	12
Band widths	80-100 MHz	250-800 MHz
Polarization	LCP+RCP	LCP+RCP
S/N ratio ($T_{quietSun} / 3\sigma T_{noise}$)	~14-16 db	>22-24 db
Dynamic range ($T_{saturation}/T_{quiet\ Sun}$)	~20 db	>32 db
Sampling rate	>30 sample/sec	~10 sample/sec
Sensitivity	~72-74 dbm	>80 dbm
ADC	16 bit	16 bit
Antenna HPBW	3.9-5.2 arc. min.	2.3-8.2 arc.min.
Internal noise generator	no	yes
Internal thermal stabilization	no	yes

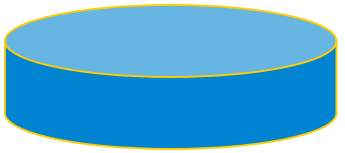
The implementation of routine solar spectral polarimetric observations with VIRAC RT-32

The SP3 (LNSP4) allows to provide routine spectral polarimetric observations of the Sun and to create of the multilevel data archive automatically. The result of the observational session is the set of 16 (12) 2D Stokes I and V maps of antenna temperatures at 3.2-4.7 (2.1-7.4 cm) cm wavelength range



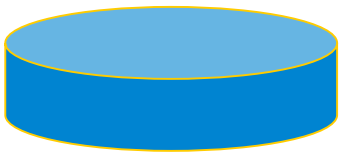
The set of hardware and software "VIRAC Solar Spectral Polarimeter"

Raw observation profiles, sky test observations, Sun transit observations, antenna position data, antenna log files, calibration data



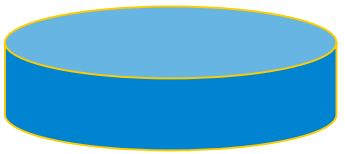
Level 0

Separate scans relatively calibrated, corrected and smoothed

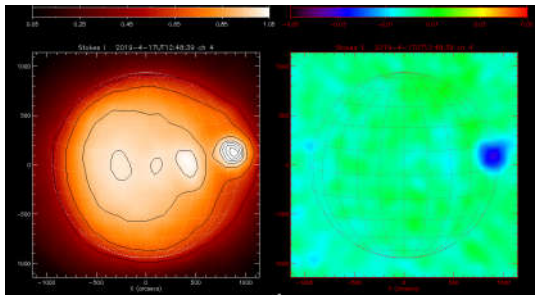


Level 1

Set of 16(12) 2D Stokes I and V maps of antenna temperatures

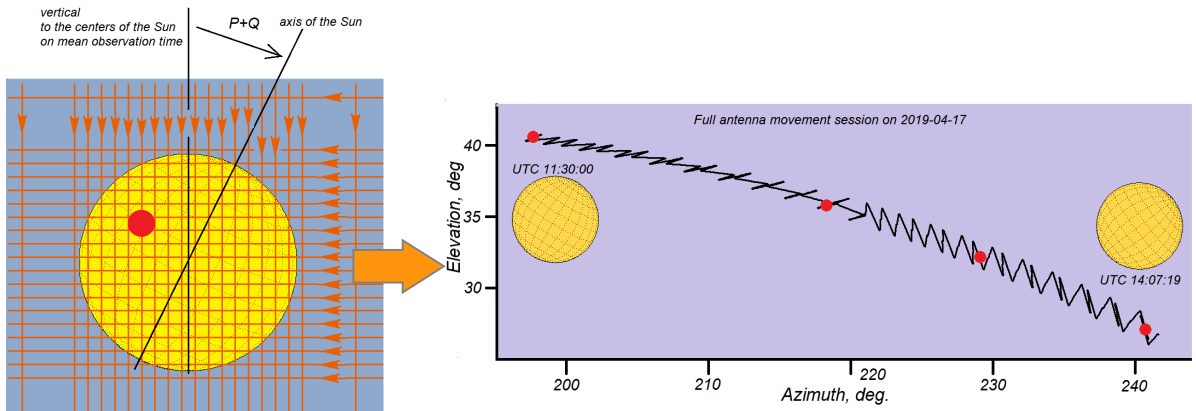


Level 2

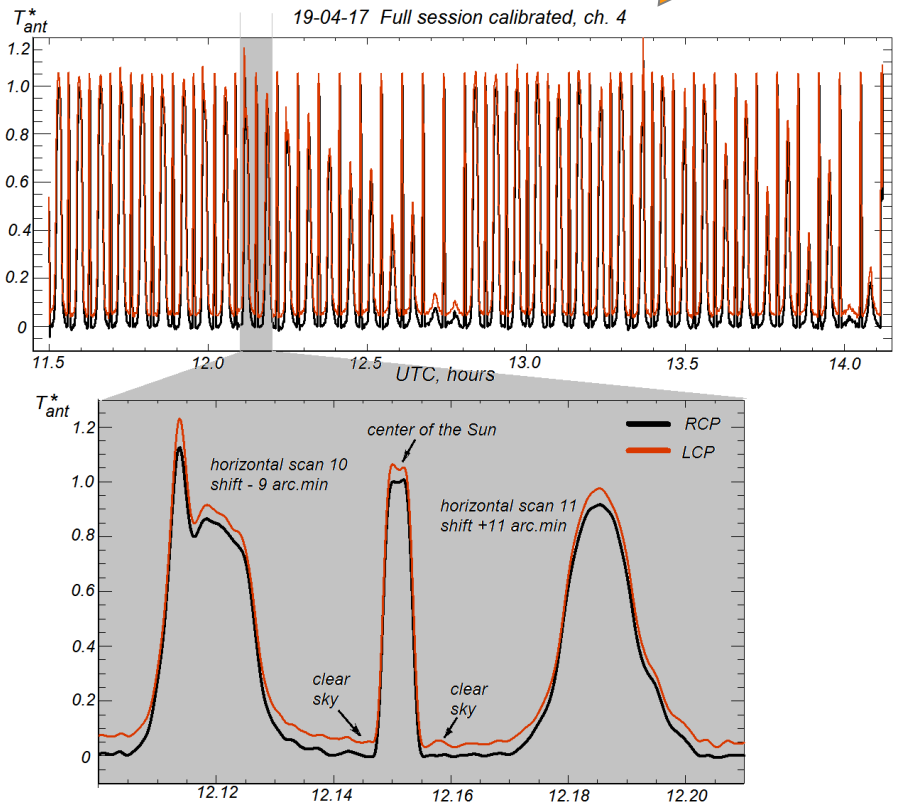


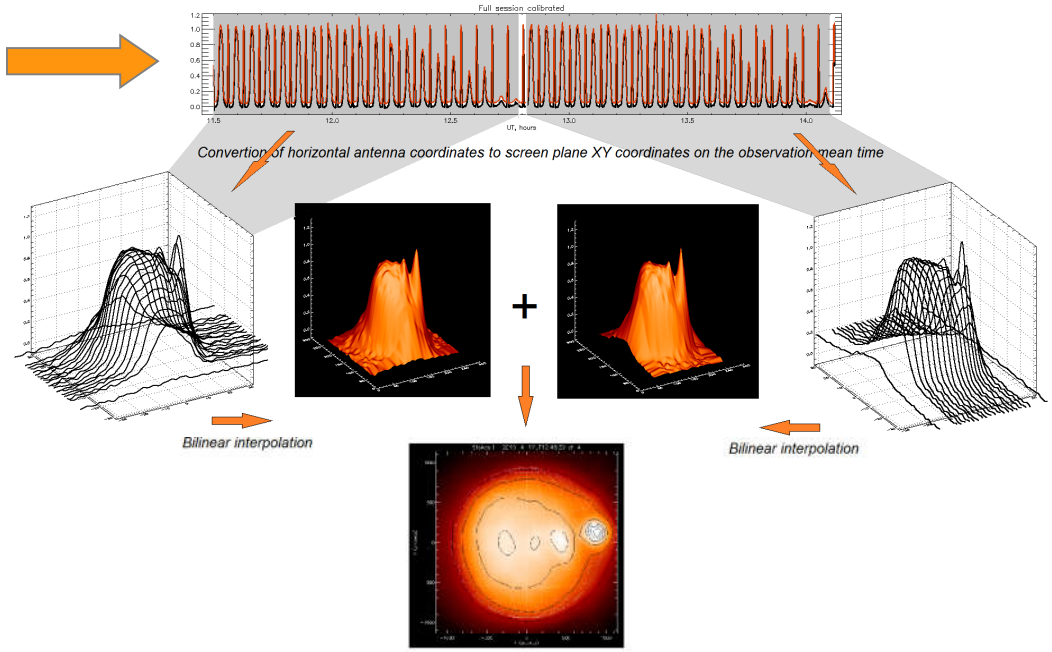
The multilevel data archive of solar observations

Methodical issues of solar 2D microwave routine observations

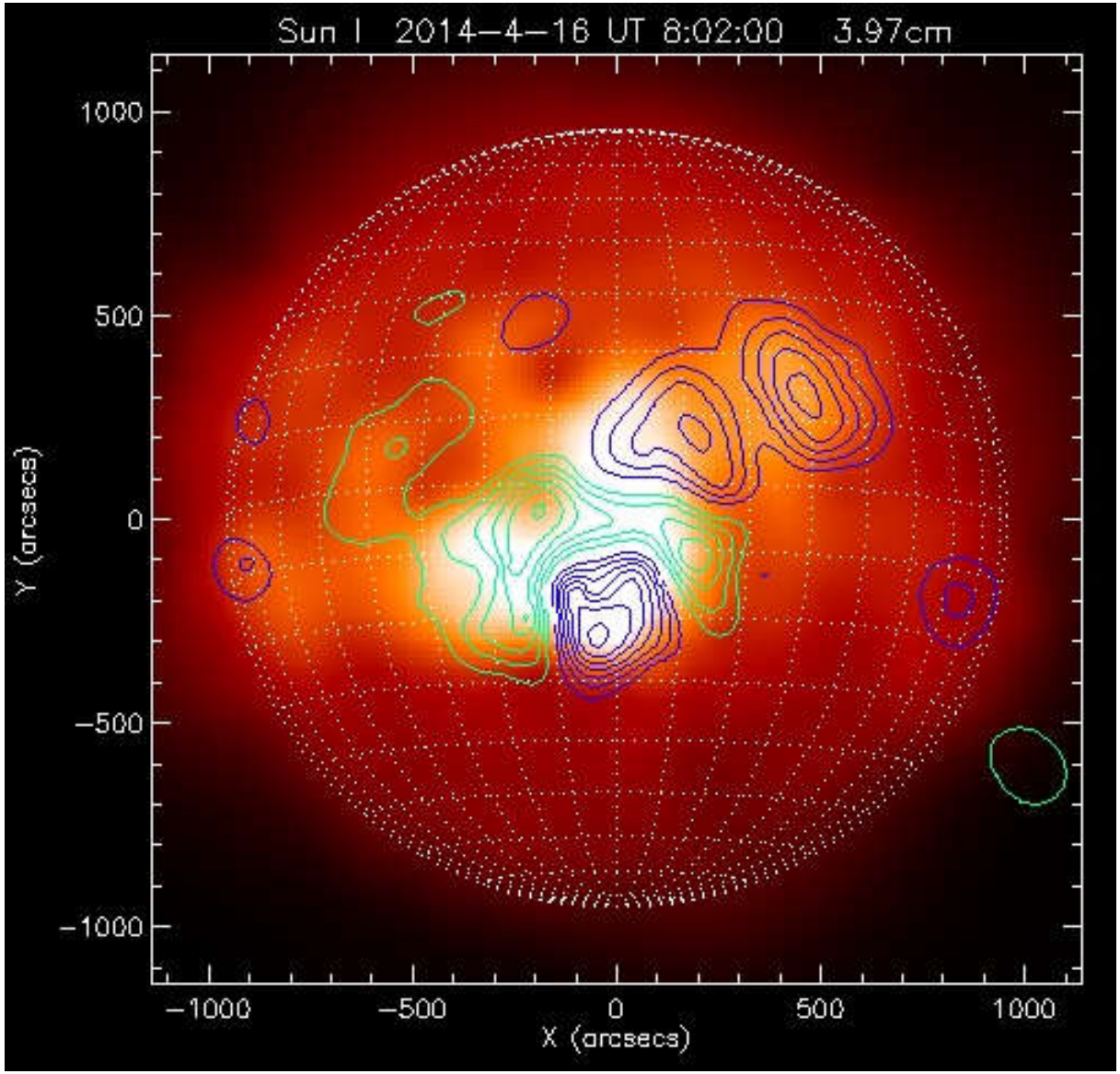


Scanning in both perpendicular directions
Relative calibration of antenna temperatures by the clear sky and the Sun centre
Conversion of the time-antenna position domain into heliographic coordinates
Construction of 2D antenna temperatures Stokes I and V distributions over the solar disk
Absolute calibration of brightness temperatures after Nobeyama Radio Polarimeter (NoRP) total flux densities observations

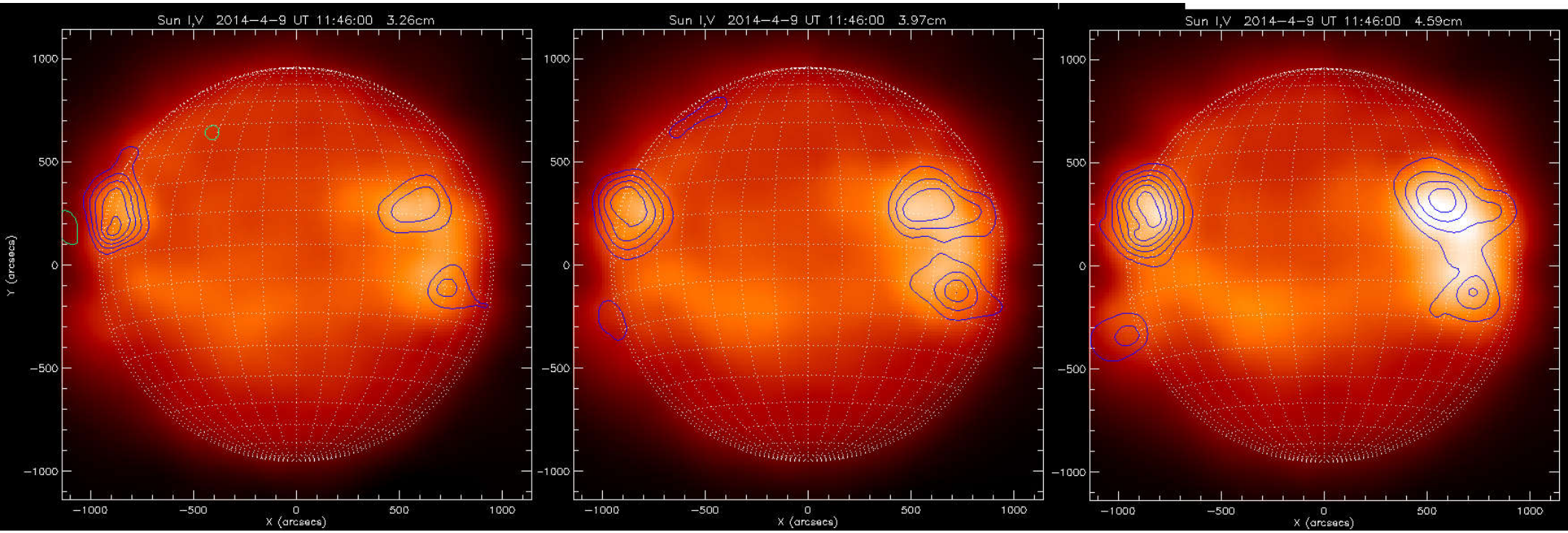




ARs polarized emission on 2014-04-16 observed with VIRAC RT-32 and Solar Spectral Polarimeter ver.3
(one of the first successful 2D solar observations)



A set of Stokes I (continuum) and V (contours) 2D solar maps for a wavelength range observed on 2014-04-09 UTC 11:48 with VIRAC RT-32+SP3

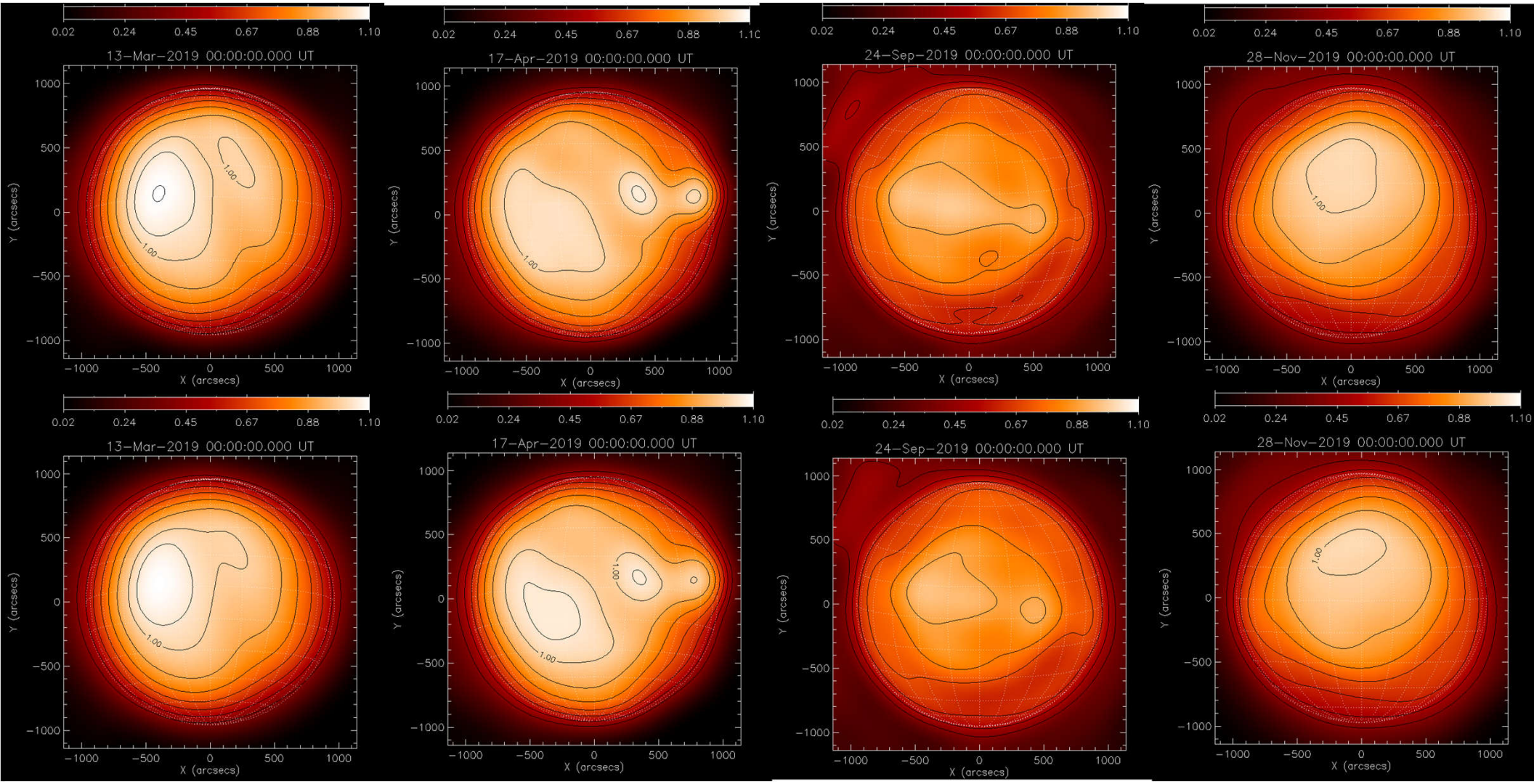


3.26 cm

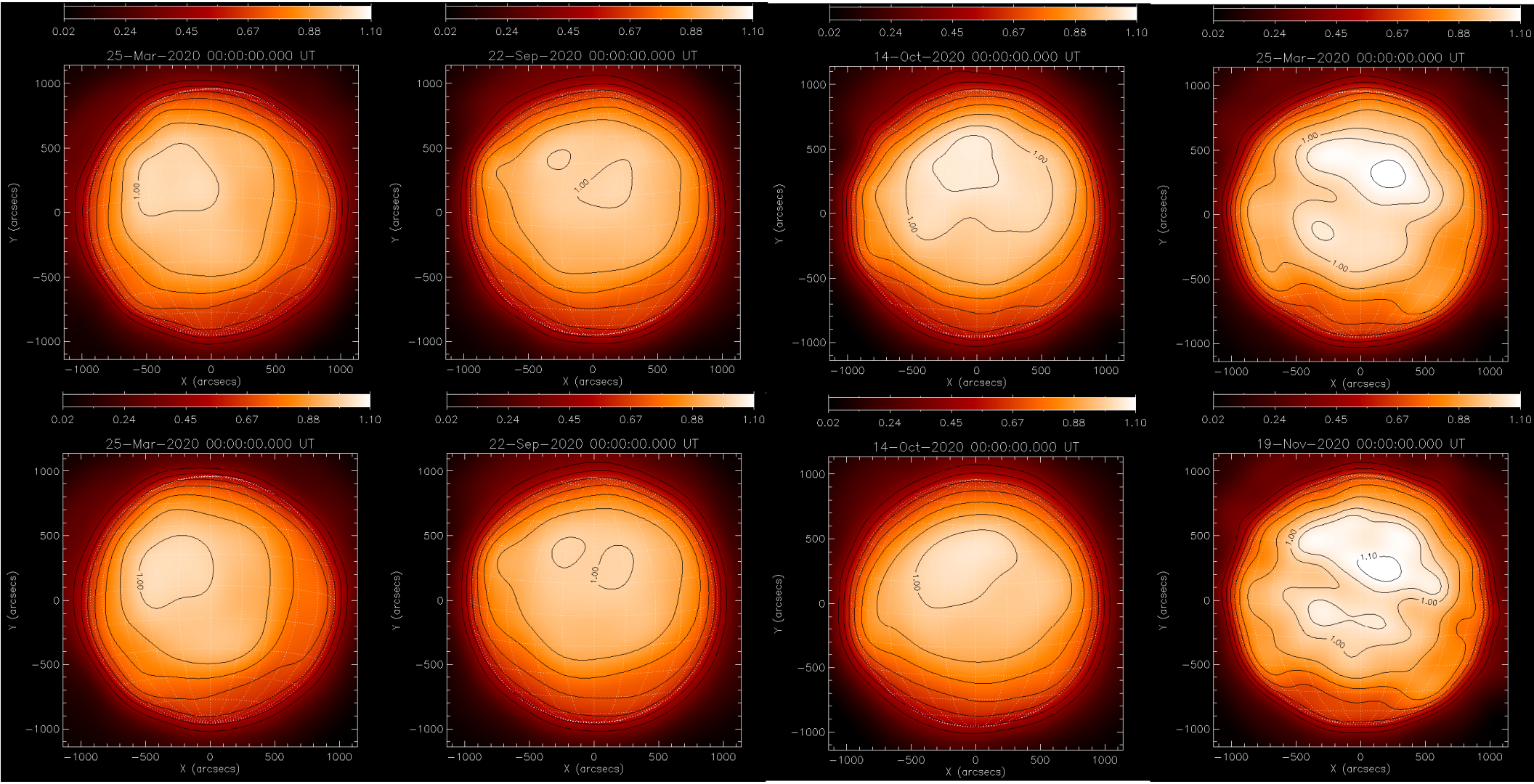
3.97 cm

4.59 cm

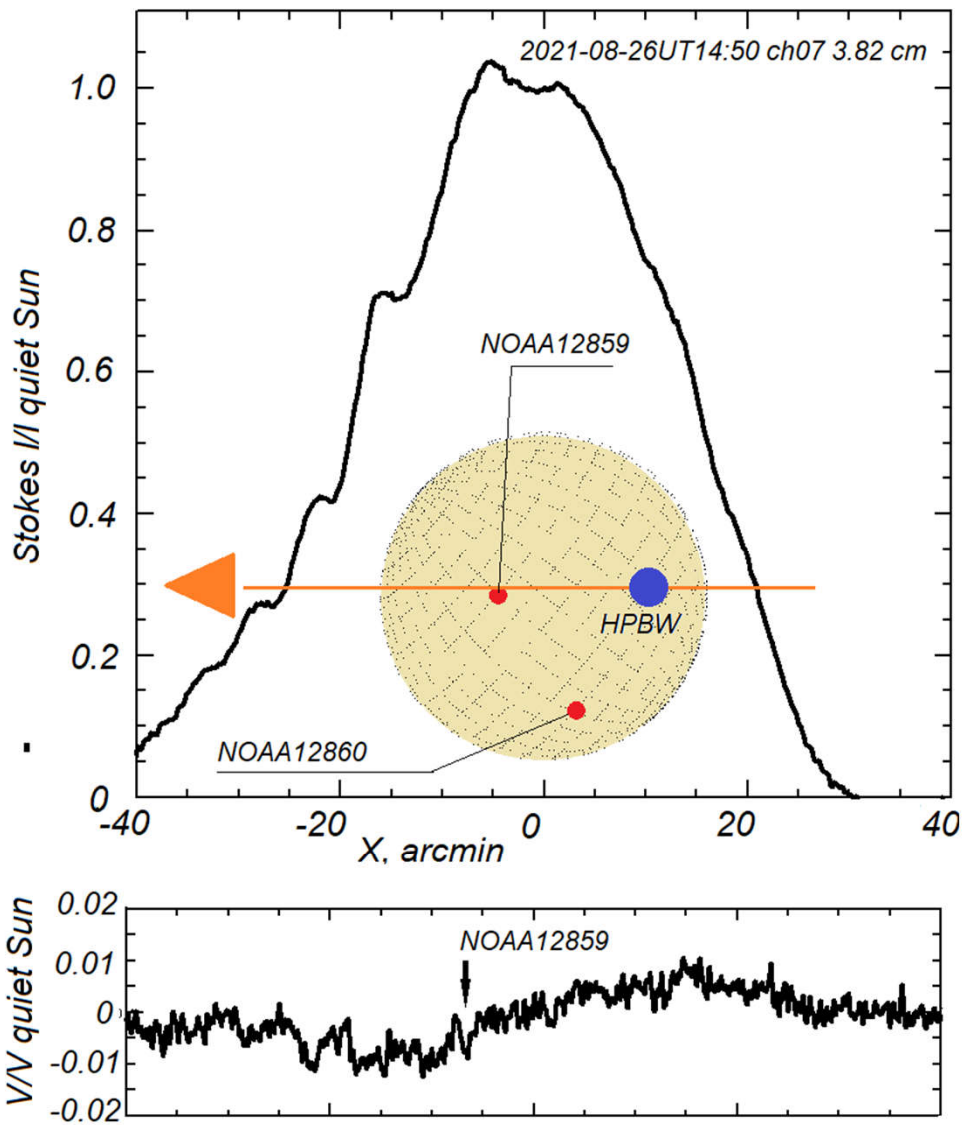
Microwave observations of the quiet Sun with SP3 in 2019

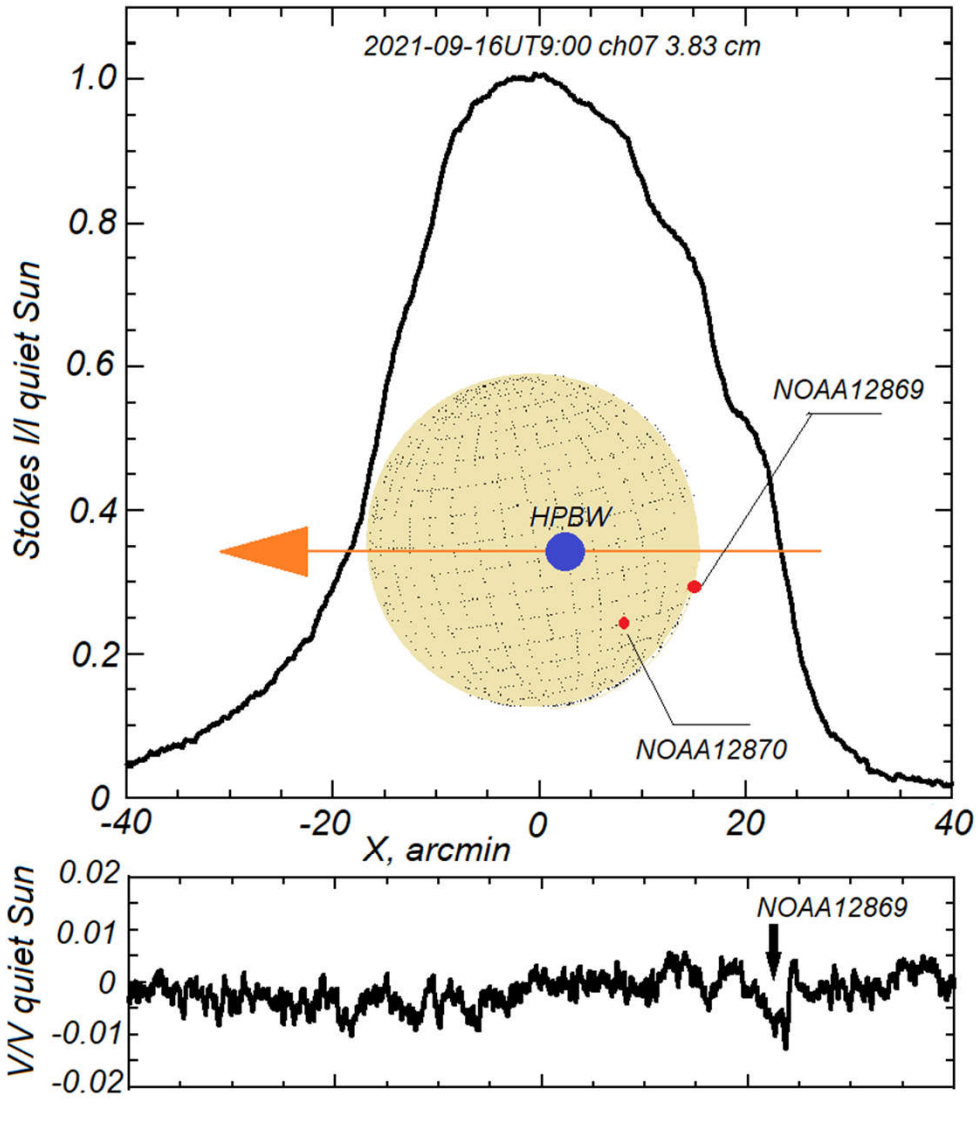


Microwave observations of the quiet Sun with SP3 in 2020



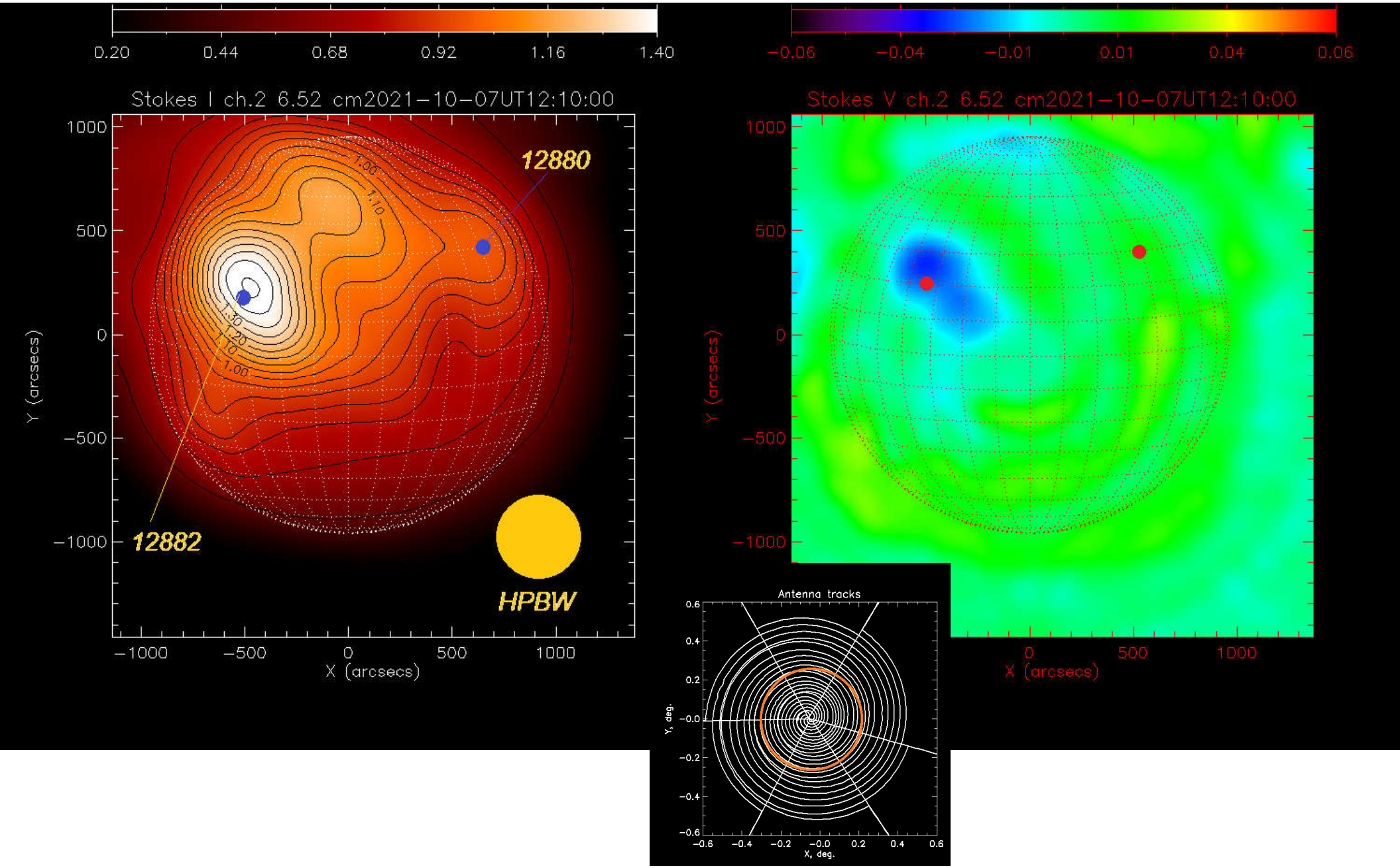
Test transits of the Sun observed with VIRAC RT-32+LNSP4 in 2021





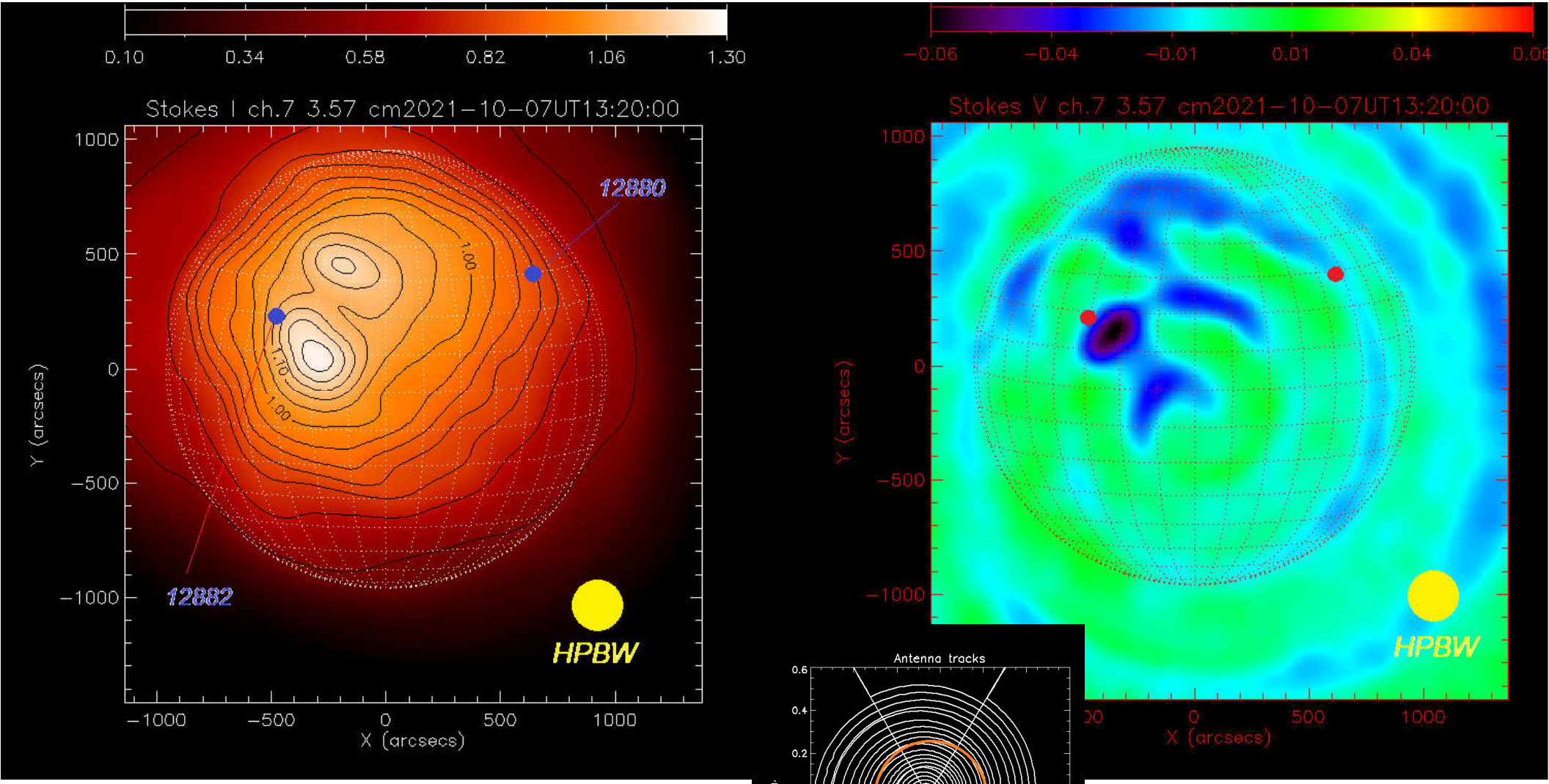
Stokes I and V records of transits of the Sun on 2021-08-26 and 2021-09-16 over RT-32 antenna beam. LNSP4, channel 7, 3.82 cm. Some side lobes of the antenna diagram and small polarization of rather weak ARs are clearly seen.

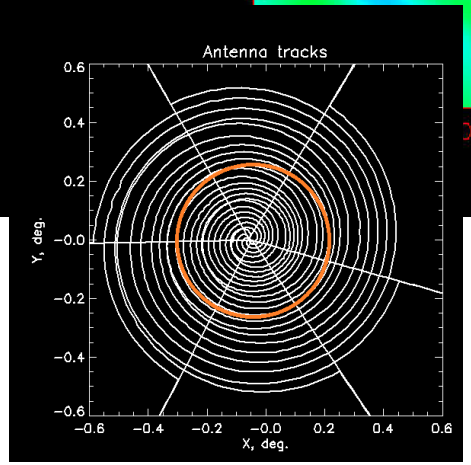
Test observations of the Sun with VIRAC RT-32+LNSP4 in 2021



2D Stokes I and V maps at 6.52 cm (ch 2) observed on 2021-10-07 with LNSP4

Test observations of the Sun with VIRAC RT-32+LNSP4 in 2021

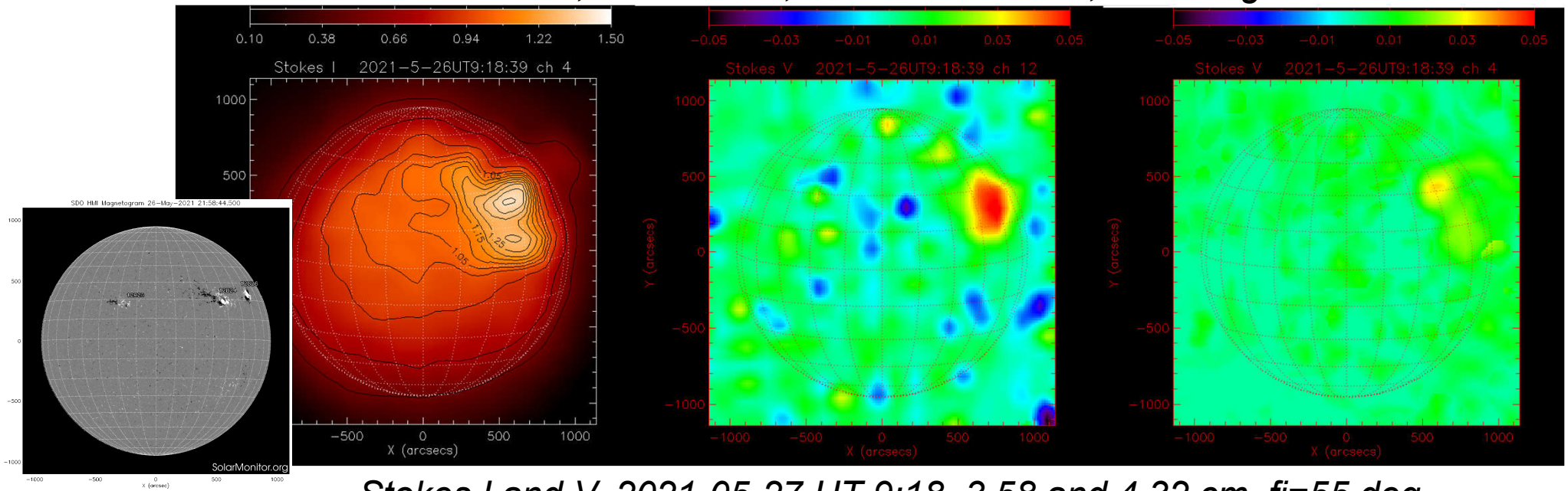




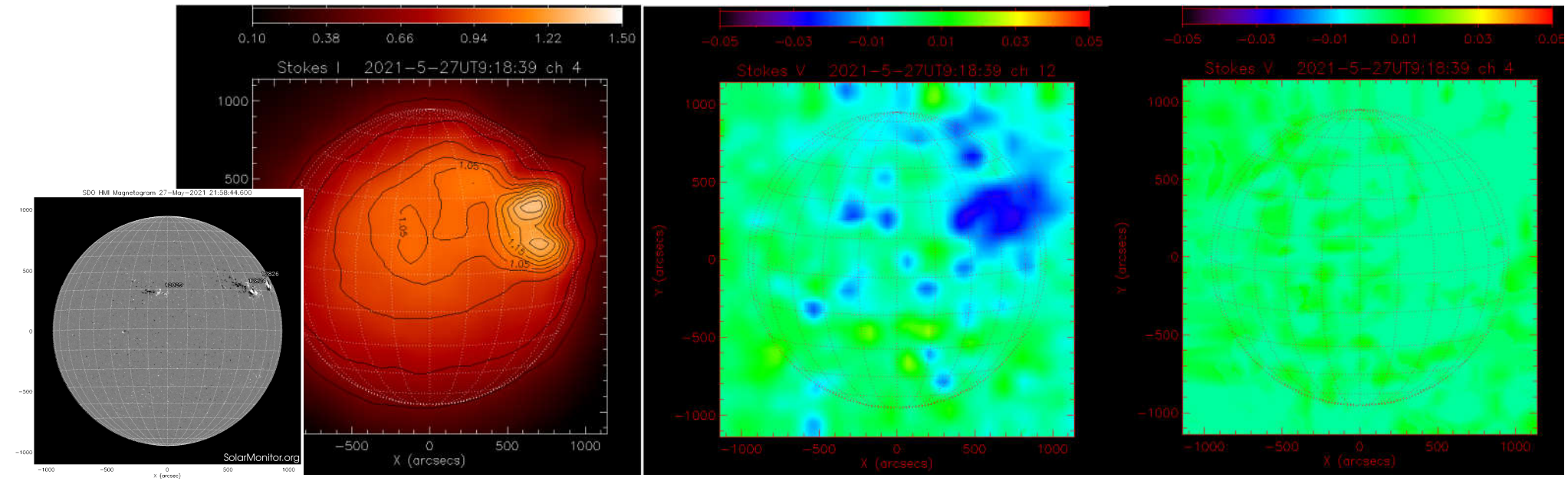
2D Stokes I and V maps at 3.57 cm (ch 7) observed on 2021-10-07 with LNSP4

The inversion of NOAA12824 polarization sign approaching the limb due to quasi-transverse propagation of the microwave emission after VIRAC observations with SP3

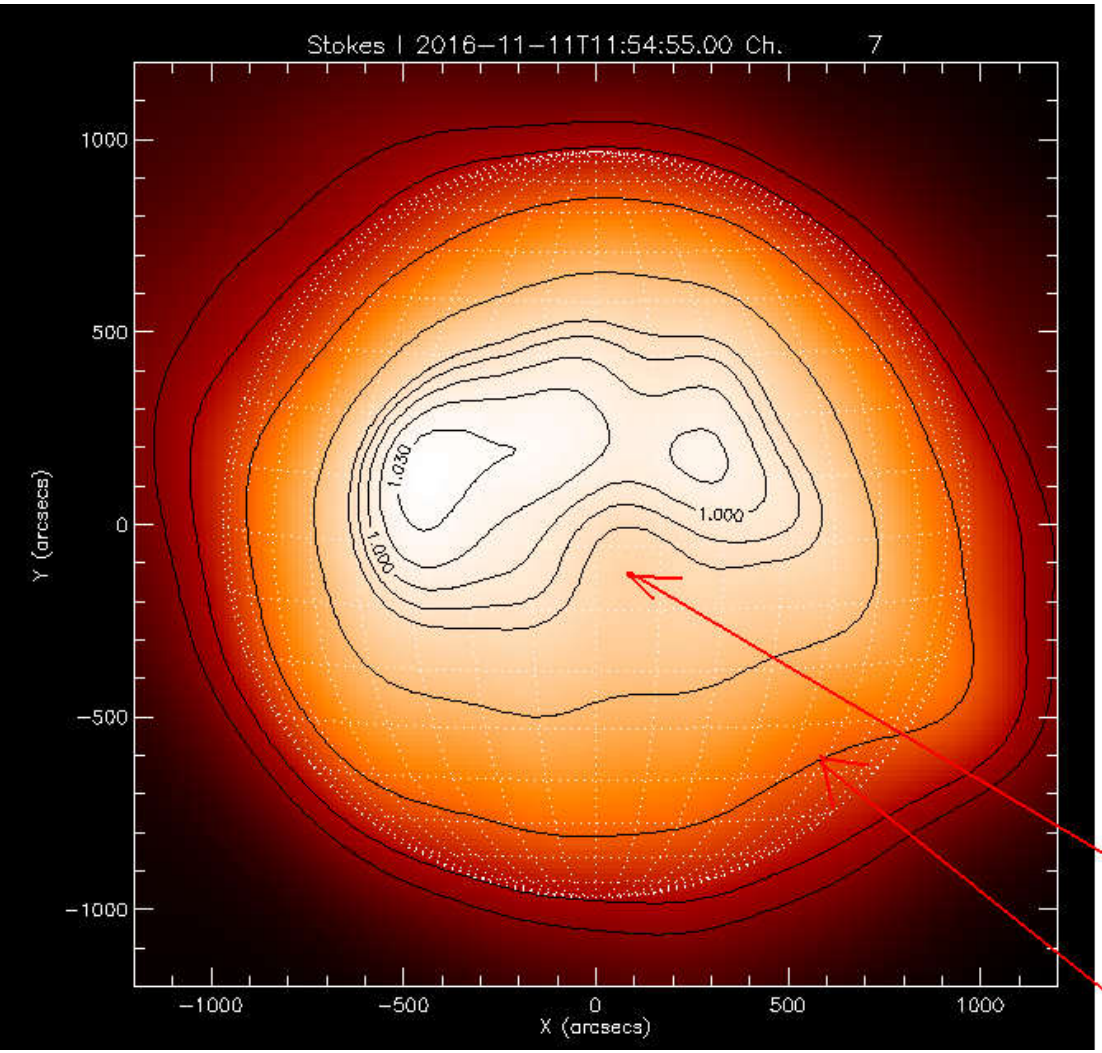
Stokes I and V, 2021-05-26, 3.58 and 4.32 cm, fi=42 deg.

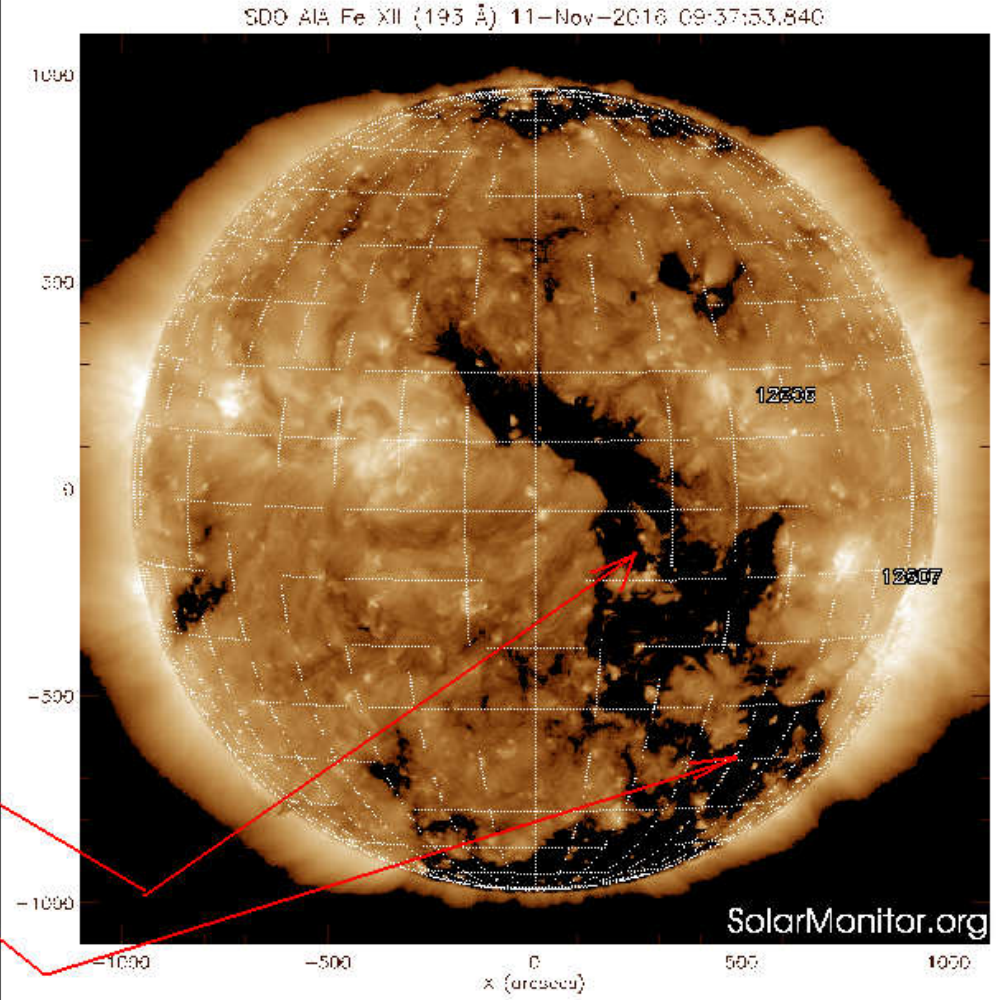


Stokes I and V, 2021-05-27 UT 9:18, 3.58 and 4.32 cm, fi=55 deg.

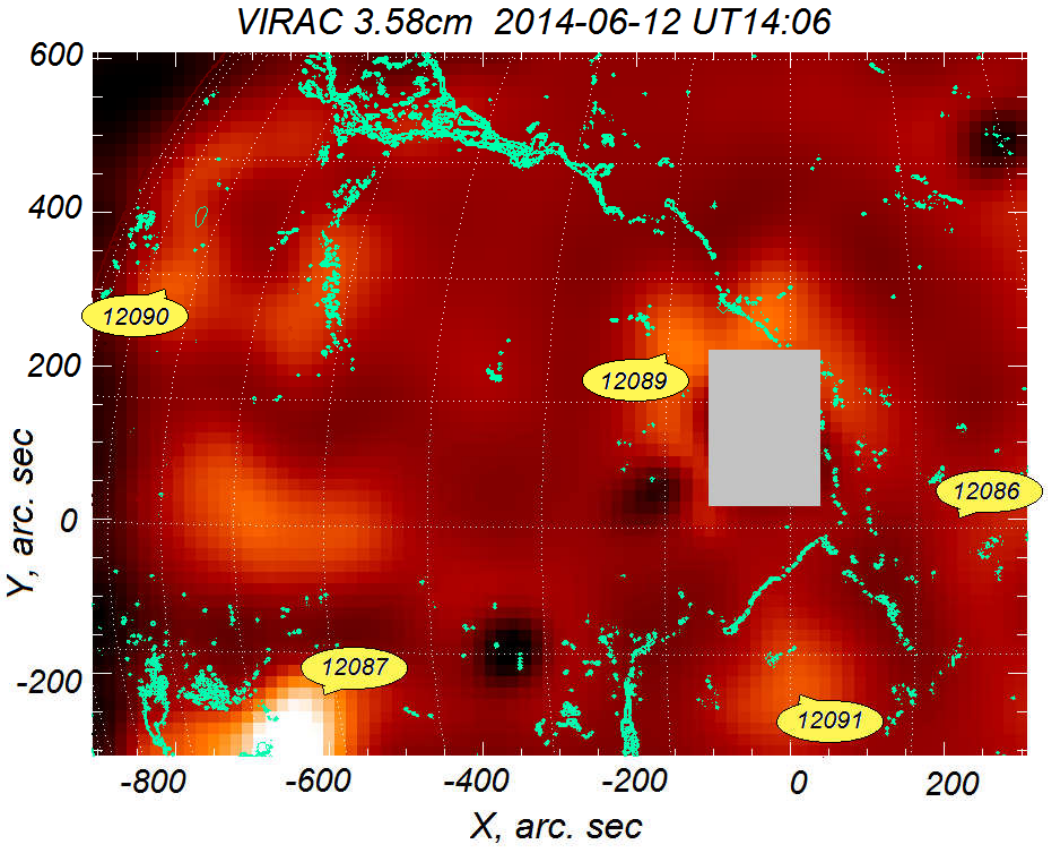


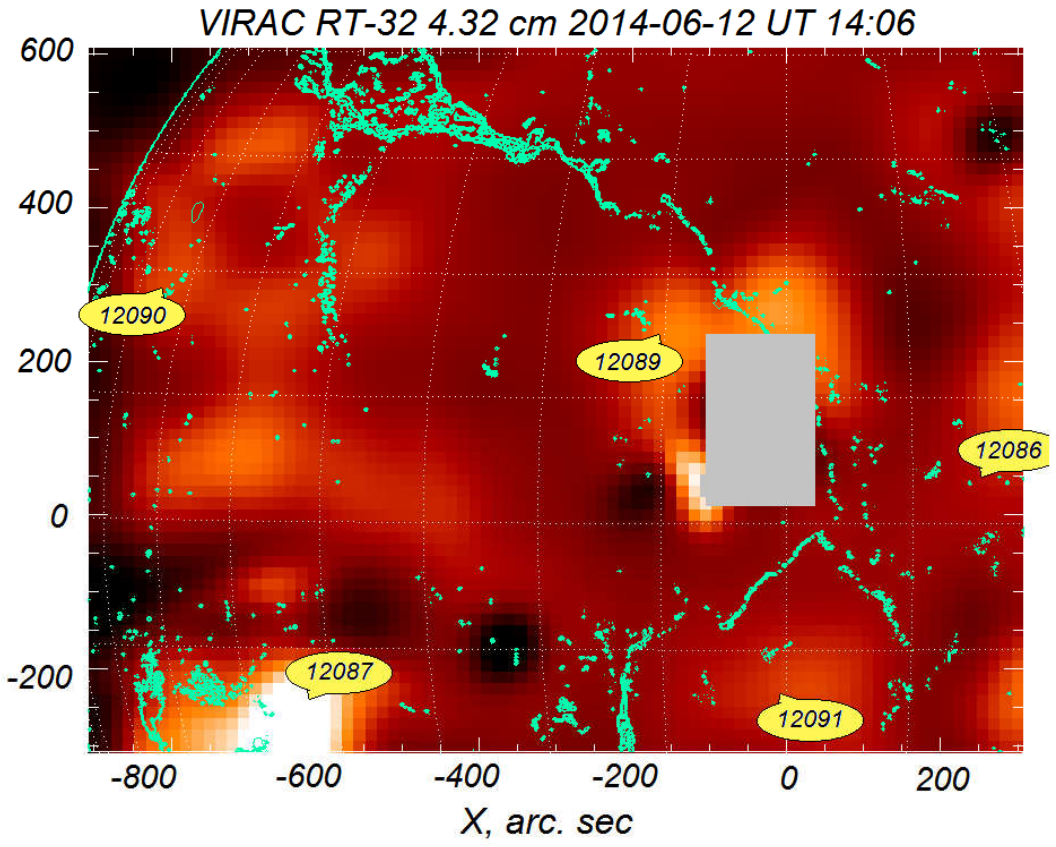
The microwave observation of coronal holes on 2016-11-11 with VIRAC RT-32+SP3 at 3.59 cm





Microwave observations of the "dark coronal corridor" which is associated with open magnetic filed elongated areas between AR 12090,12089 and 12091





The superimposition of the squashing Q factor (green dots), (PFSS simulation of B. Ryabov) and total intensity maps with areas of the emission depression (continuum) for 3.58 cm (left) and 4.39 cm (VIRAC RT-32) (right) after enhanced calibration, MLM cleaning, wavelet noise reductions and contrast enhancements. The same certain spatial shift of depression areas and Q-factor location needs to be discussed.

Feasible tasks and problems

Observations of large-scale and low contrast coronal structures

Studies of radio brightness of the quiet Sun and coronal holes

Analysis of coronal hole-like extend structures associated with open magnetic fields which could be expected as sources of the slow solar wind

Analysis of active regions associated with large isolated sunspots

Revealing the large-scale coronal loops as immediate relatives of distant active regions so as to reproduce sympathetic solar flares

Observations of microwave flux fluctuations in local sources

Analysis of the radio flux fluctuations resulting from the magnetic field emergence in active regions

Analysis of the radio flux fluctuations preceding a solar flare

Coronal magnetography

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

Conclusions

- Nowadays VIRAC has all of possibilities to provide microwave spectral polarimetric observations of the Sun with the multichannel spectral polarimeters at 3.2-4.7 cm and 2.1-7.4 cm wavelength ranges for numerous solar physics problems
- The newly developed spectral polarimeter with expanded wavelength range and enhanced noise parameters and dynamic range is able to clearly and reliably observe areas of reduced brightness temperatures (“Low Temperature Regions” - LTR) and study coronal holes and coronal hole-like structures

Thank you!