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**RATAN-600 magnetic field diagnostics.
RATAN-600 resources and available data.
Role of RATAN data in model validation.**

Spectral-polarization data in the 3-18 GHz band are provided by observations with RATAN-600 (Radio telescope of Russian Academy of Sciences)

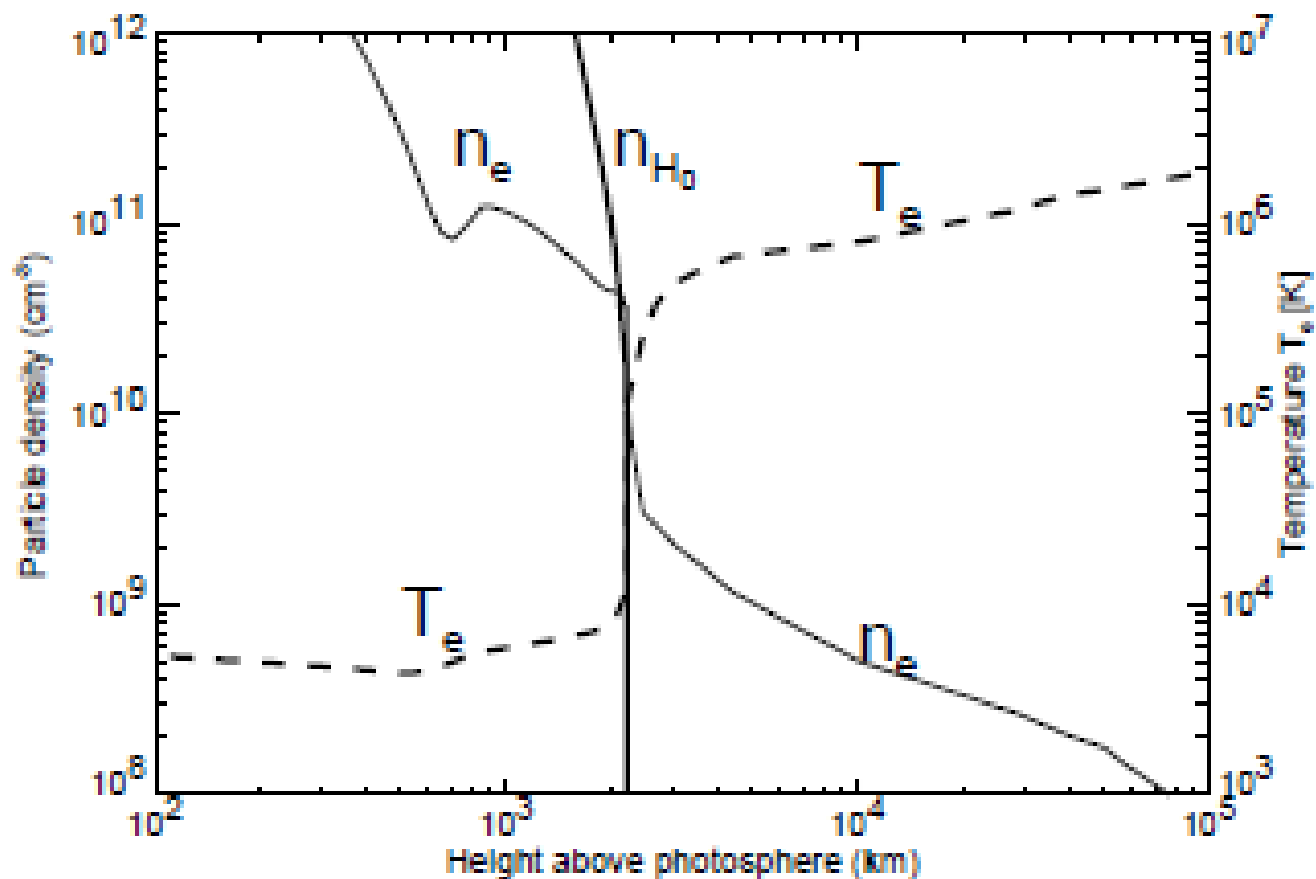


Bogod V.M. RATAN-600 radio telescope in the 24th solar activity cycle. I. New opportunities and tasks, Astrophys. Bull., V. 66, № 2, P. 190–204, 2011.

For AR research, RATAN-600 data can be useful, for example, for estimating the spatial (one-dimensional, up to 18 arc secs) and spectral (with a frequency resolution of up to 1%) structure of the active region. Spectral-polarization data allow us to make estimates of the magnetic field. Multi-azimuth observations give an idea of the evolution and dynamics of the active region with a time step equal to the time between observations in azimuths (from 8 to 40 minutes). For several events this is enough for changes in intensity and polarization to be noticeable. Higher temporal resolution of RATAN-600 is expected in the future after the introduction of new modes into regular observations: tracking mode and multiple scanning, which are currently being tested.

Radio astronomical methods are important tools for the study of the solar atmosphere because they provide the data about the parameters of active plasma over a wide range of heights that are difficult to probe using other methods.

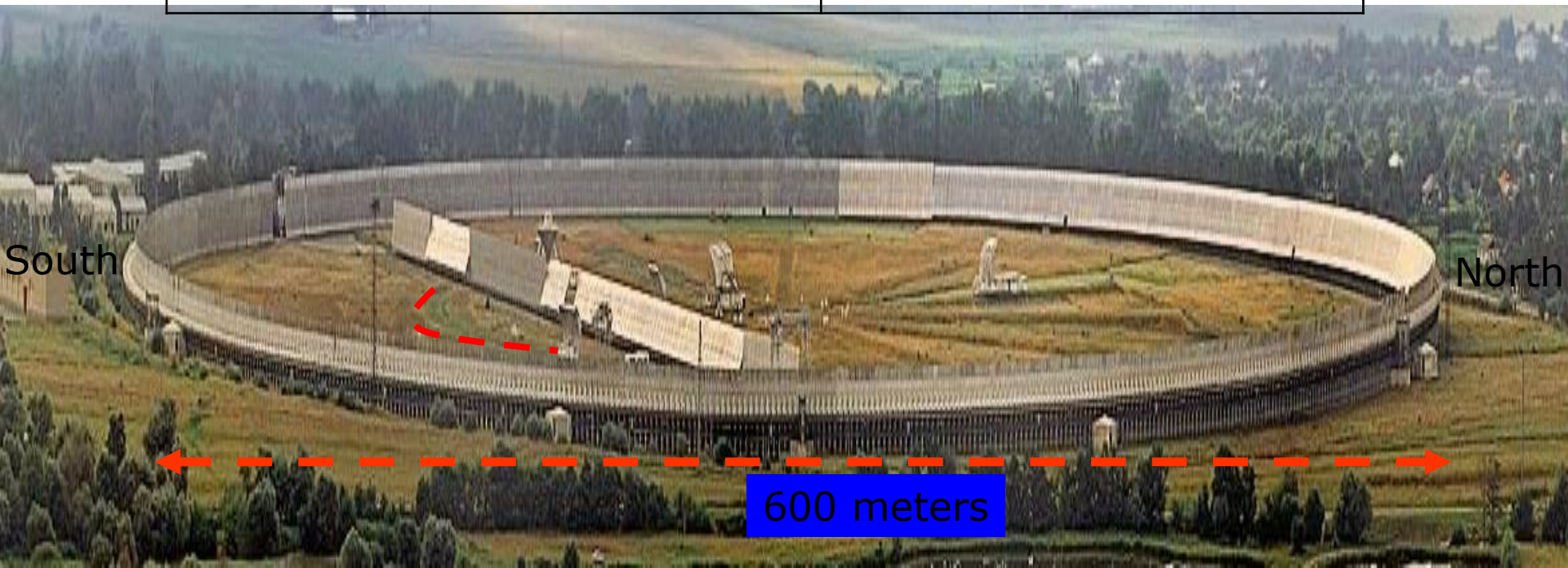
The radio emission of the chromosphere can be observed at mm-wave frequencies, whereas the transition region between the chromosphere and the corona and the lower corona radiate efficiently at centimeter- and decimeter-wave frequencies.



Electron density and temperature model of the chromosphere (Fontenla et al. 1990; Model FAL-C) and lower corona (Gabriel, 1976).

RATAN-600 parameters for solar research

	range	resolution
Spectral	1-18 GHz	1%
Spatial		~15 arcsec x 17 arcmin at 18GHz
Temporal	7-11 UT	4 min cadence
Other parameters:		
Circular polarization accuracy of measurement		1-10%
Flux sensitivity		0.1 s.f.u.



RATAN-600 has a spatial resolution in the CM-range of 10-60 arcsec, in the DM-range 1-5 arcmin, in MM-the range of 2-10 arcsec. In this case, the sensitivity of the brightness temperature at all ranges is about 0.1 of the brightness temperature of the Sun, taking into account all factors of dispersion in the antenna.

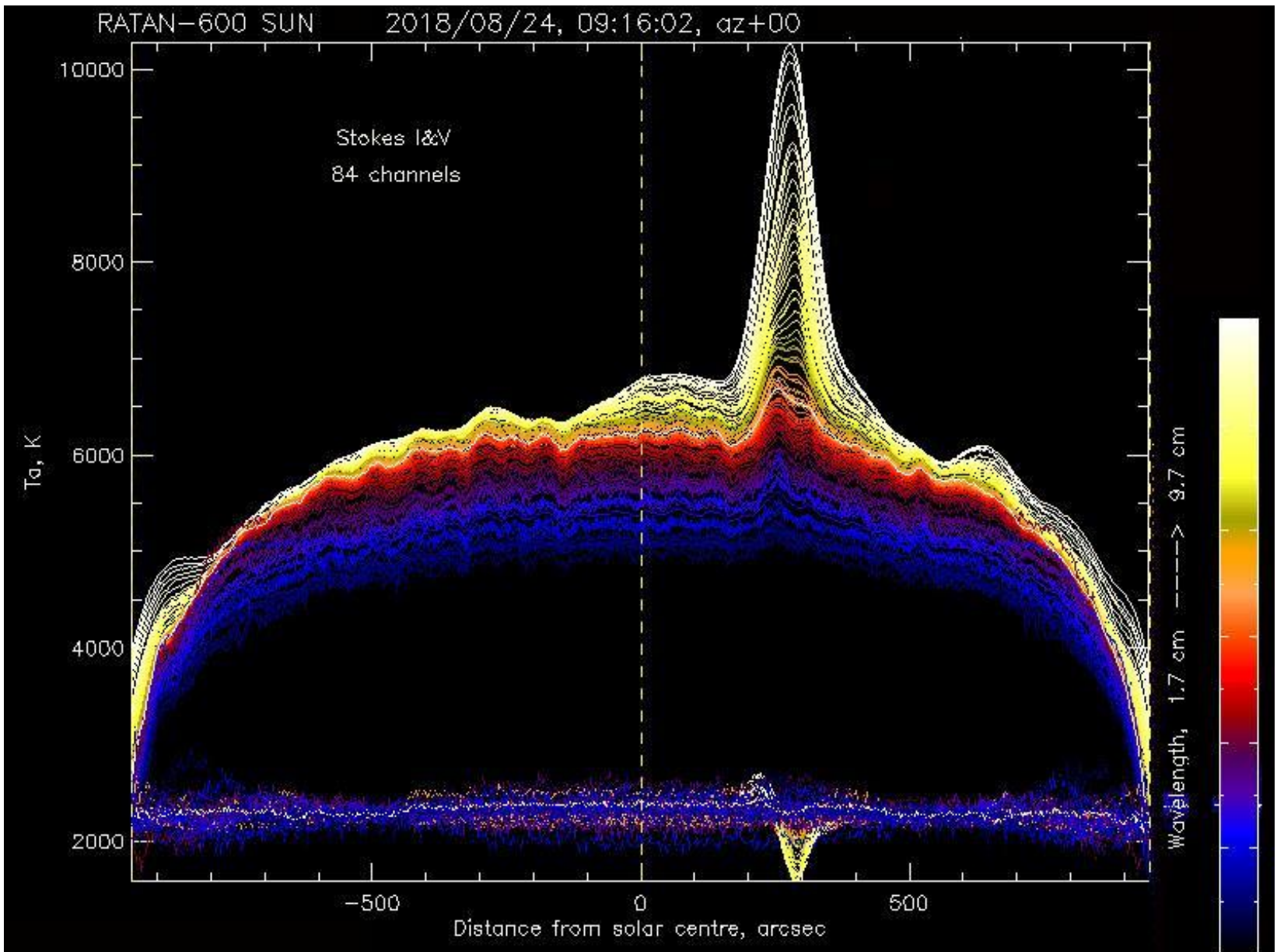
$$\text{HPBW}_h \text{ (arcsec)} = 8.5 \times \lambda$$

$$\text{HPBW}_v \text{ (arcmin)} = 7.5 \times \lambda$$

The RATAN-600 archive containing solar data starting from 1997

is available on site <http://www.spbf.sao.ru>

9-13 UT in the range from 1.67 cm up to 32 cm with left and right circular polarization



- The RATAN-600 archive of daily solar observations starting from 1997 (7-11 UT in the range from 1.67 cm up to 32 cm with left and right circular polarization) is open for investigations.
- The spectral-polarization observations over a wide wavelength range reveal numerous intensity and polarization effects reflecting the characteristics of active regions at not-flaring state, and sometimes also at the pre-flare, flare and post-flare stages.
- The frequency range covers the gyroresonance emission from all the active regions, corresponding to the magnetic field strengths found in the corona (up to 2500 G), and other emission mechanisms, being able to indicate the preflare state and monitor the solar flare activity.

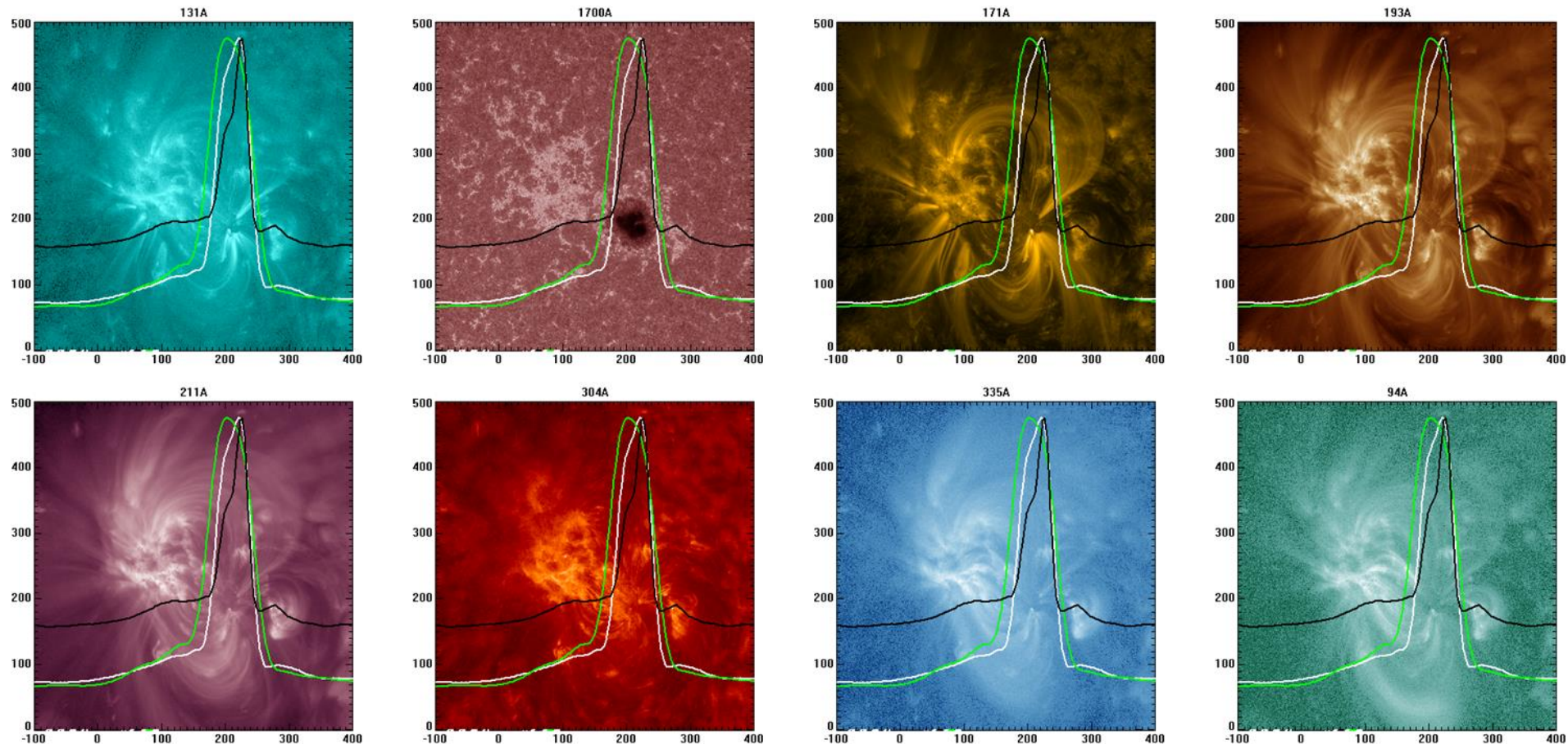
1) The composition of this active regions magnetosphere:

Plage - increased brightness over the chromospheric flocculus

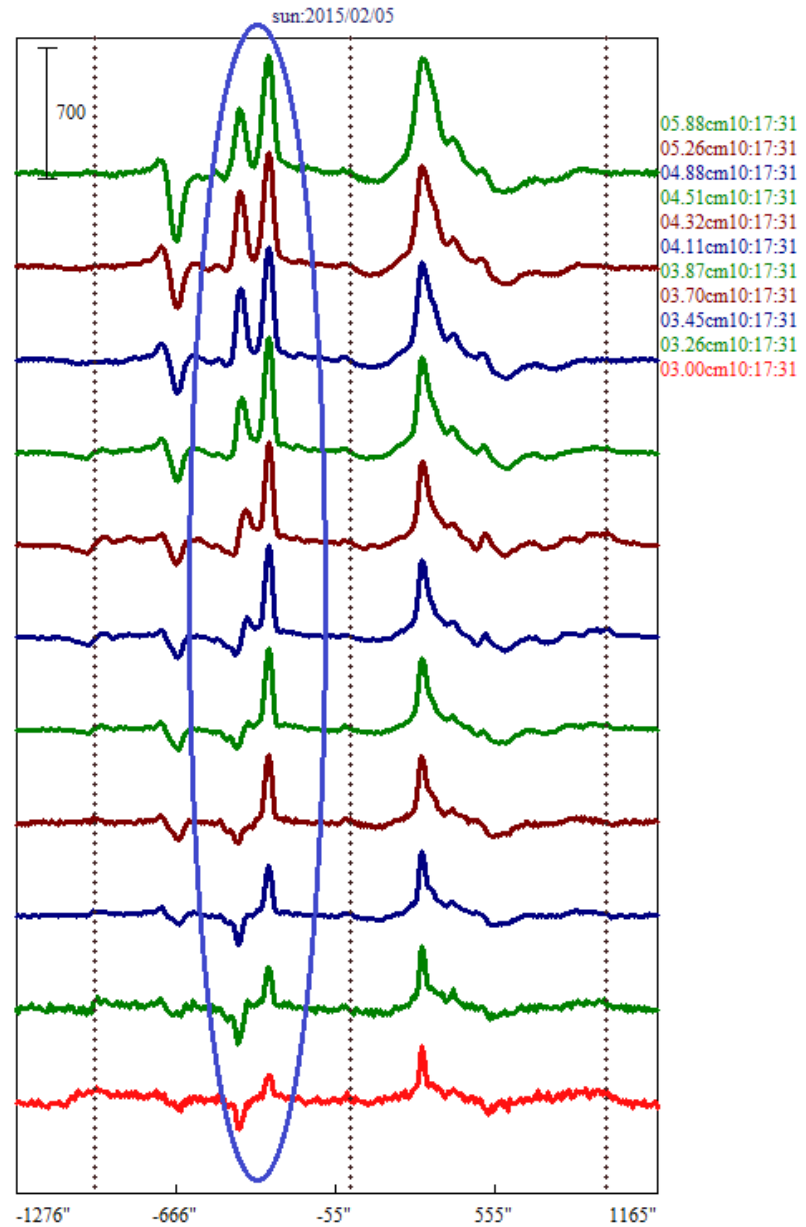
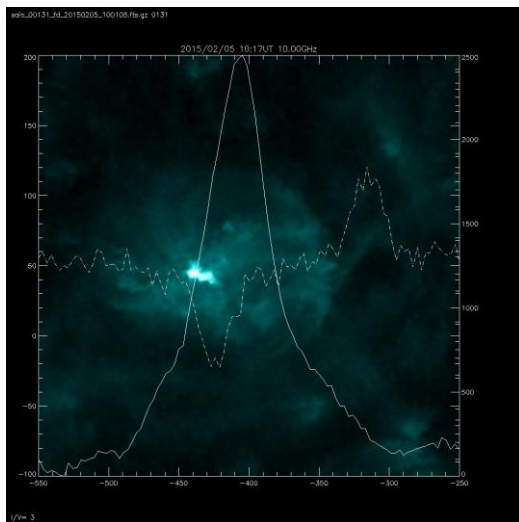
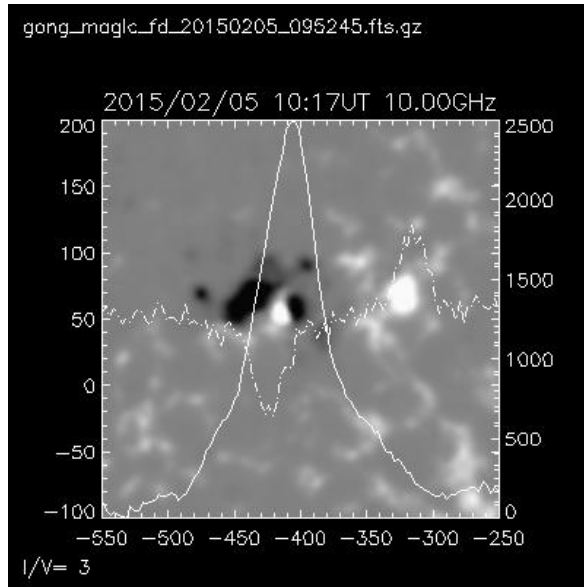
Spot component - over local areas of strong magnetic fields, which in visible light is darker than the surrounding photosphere (spots), and in radio emission - bright polarized sources

Halo - arcade of coronal loops

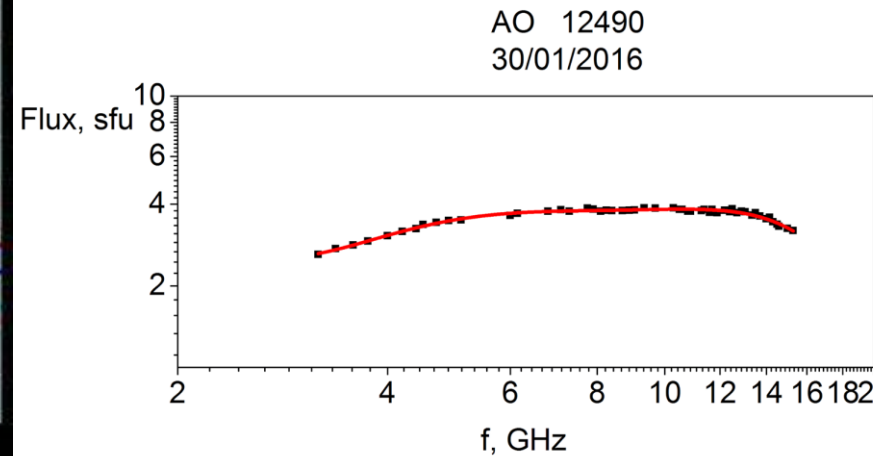
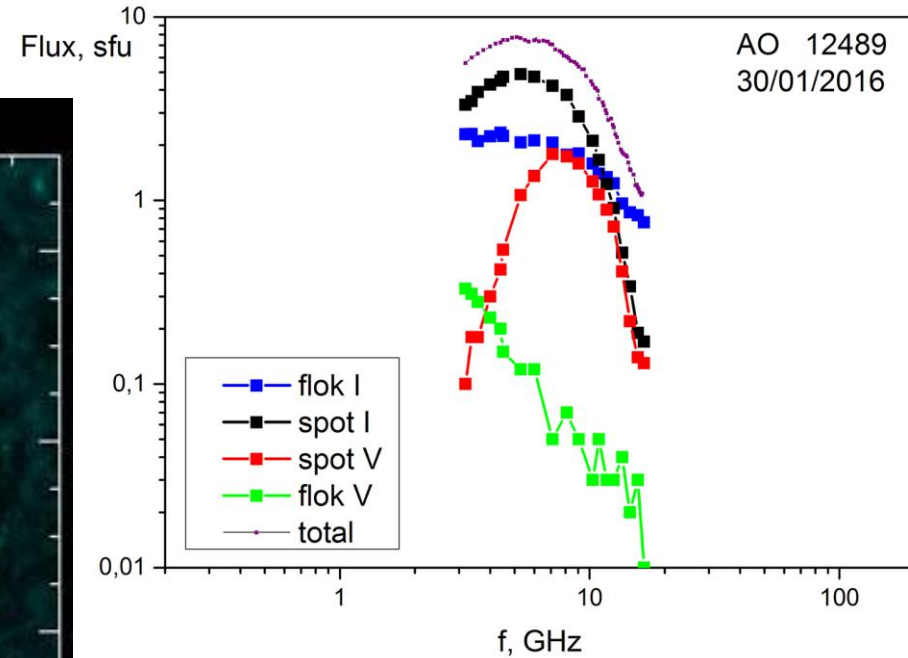
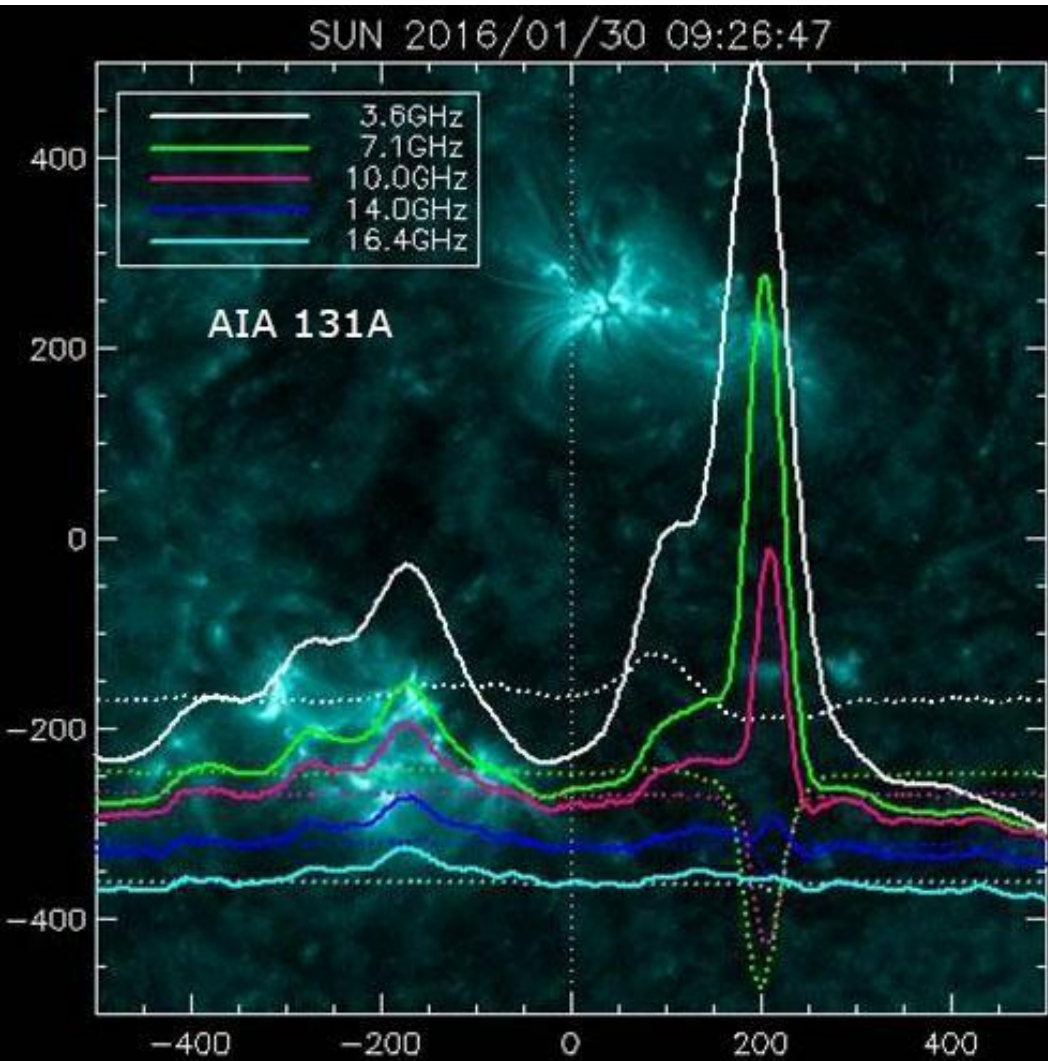
RATAN-600: I(solid), V(dashed) 15.7 GHz (black), 9.75 GHz (white), 6.80 GHz (green)



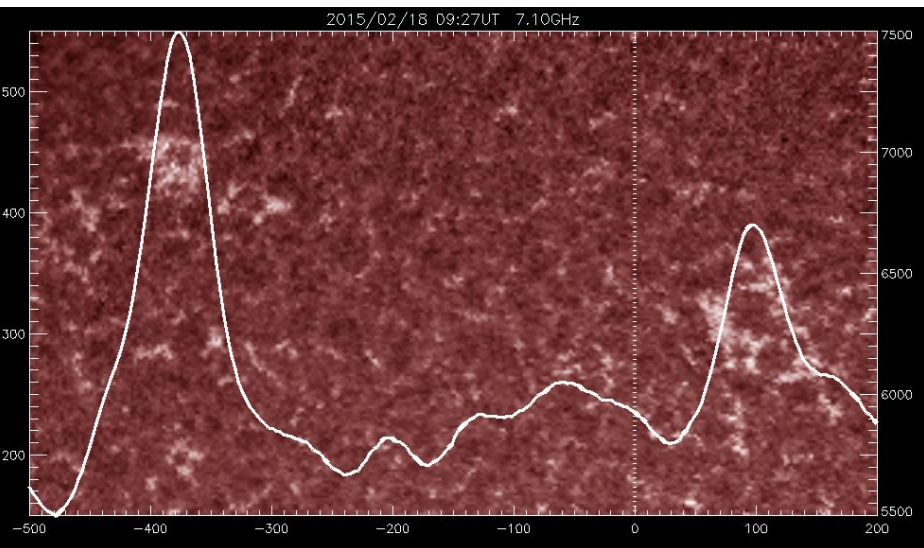
2) The complexity of the magnetic configuration by polarization scans: α, β and the inversion



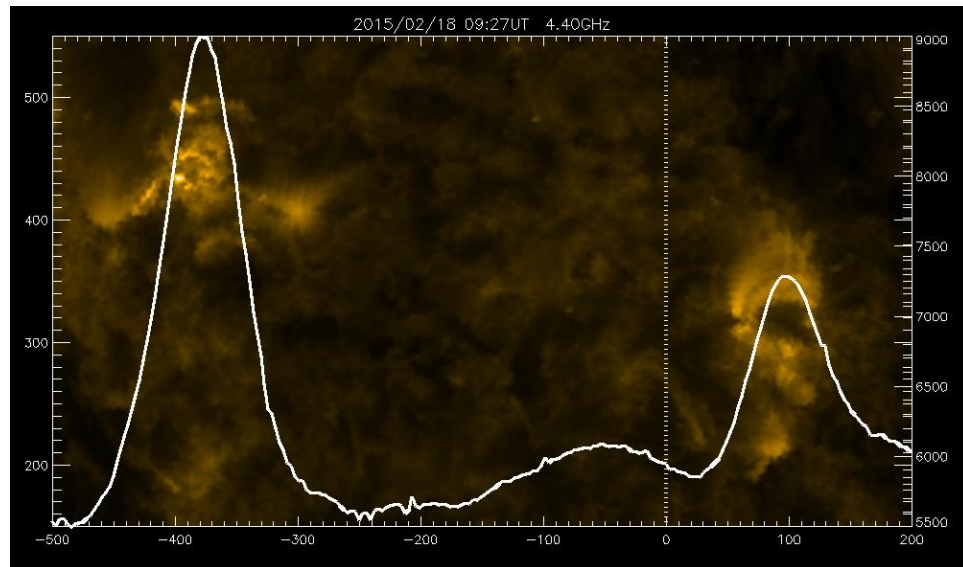
3) The study of the physical nature of solar active region magnetospheres by the spectrum of microwave emission



Magnetosphere with the Plage component only

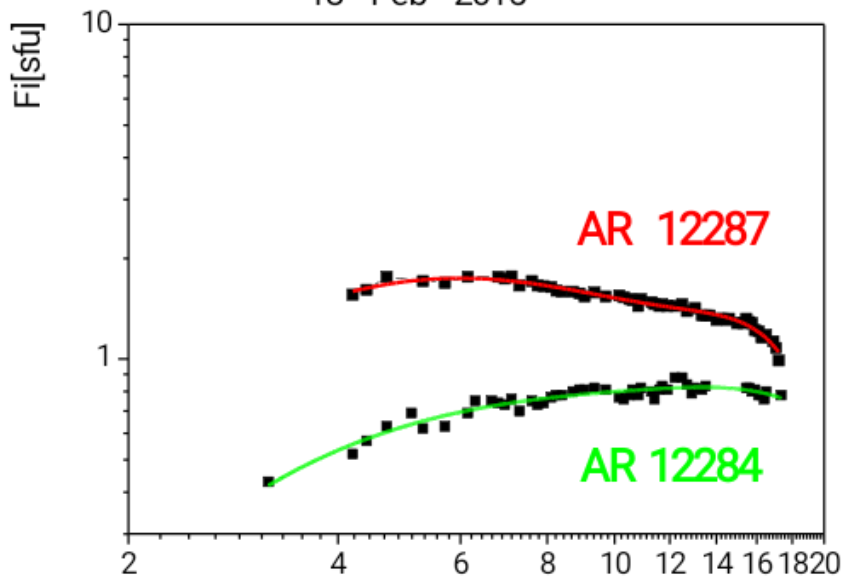
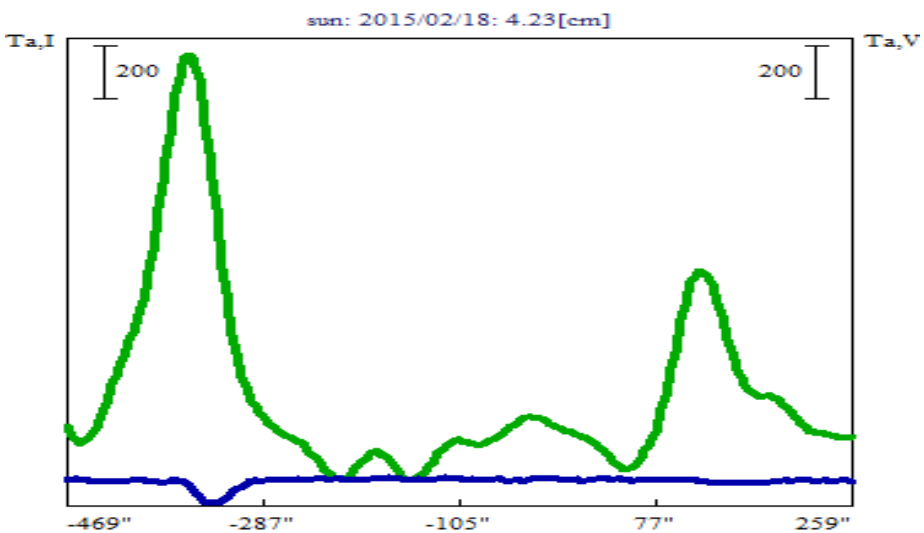


SDO 1700 A, RATAN-600 7.1 GHz



171 A, 4.4 GHz

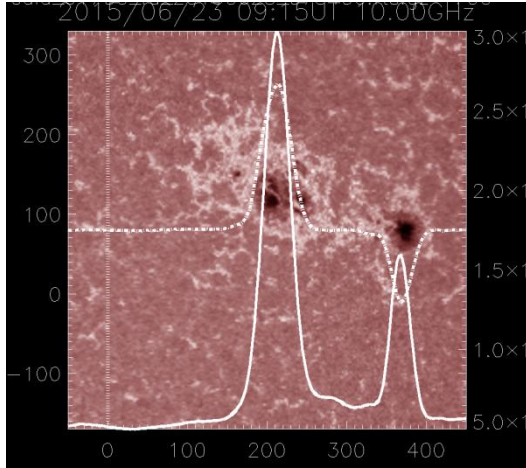
18 Feb 2015



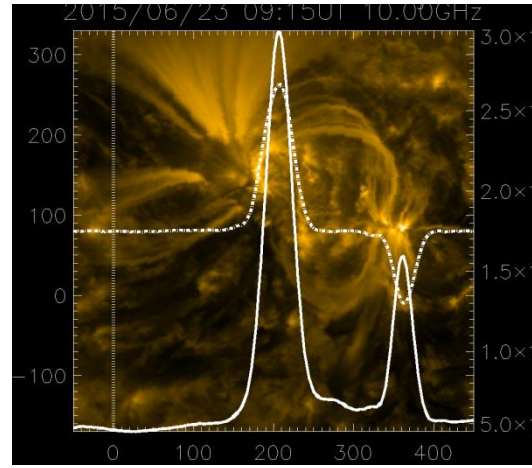
Magnetosphere with a bipolar Sunspot group (with a positive and a negative polarity)

23 June
2015

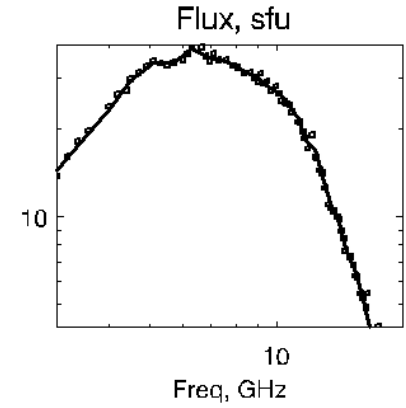
AR
12371



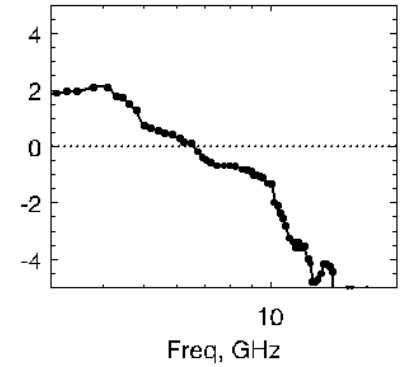
1700 Å, 10 GHz



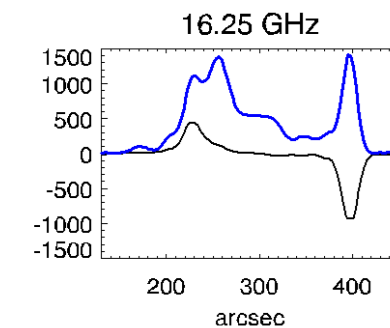
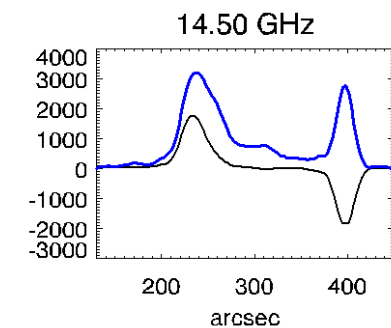
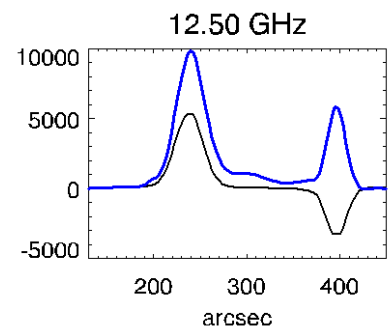
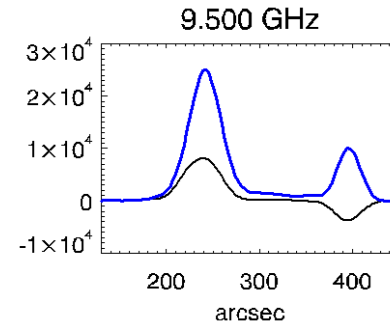
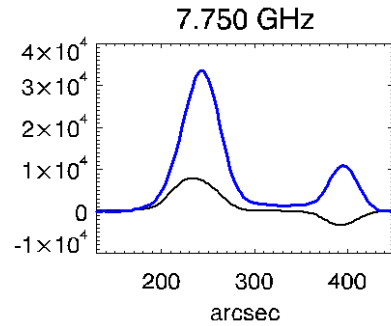
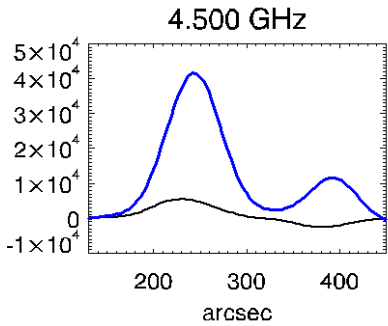
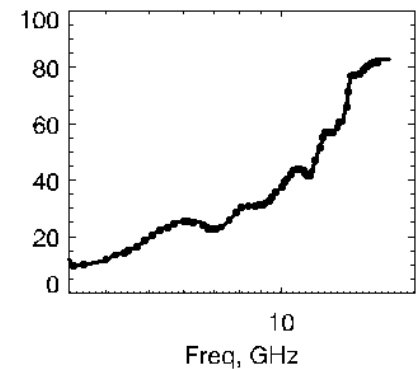
131 Å, 10 GHz



Spectral index



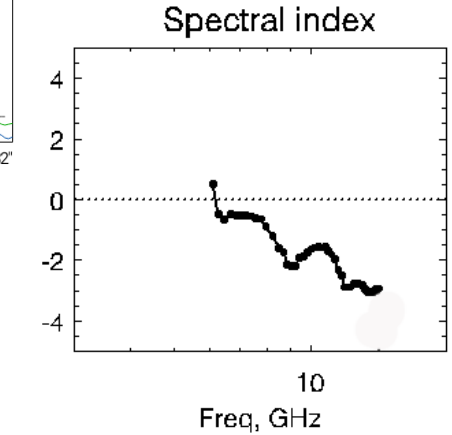
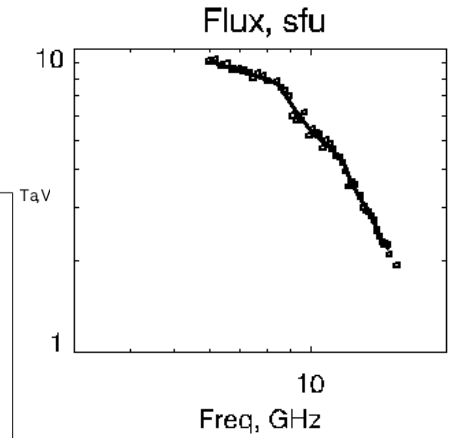
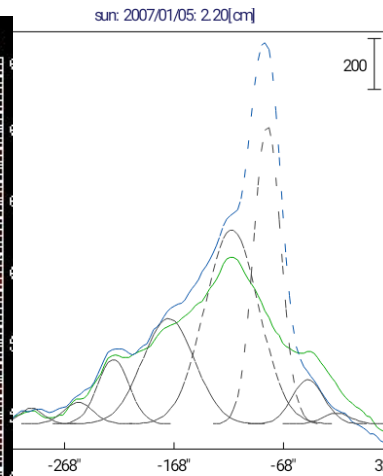
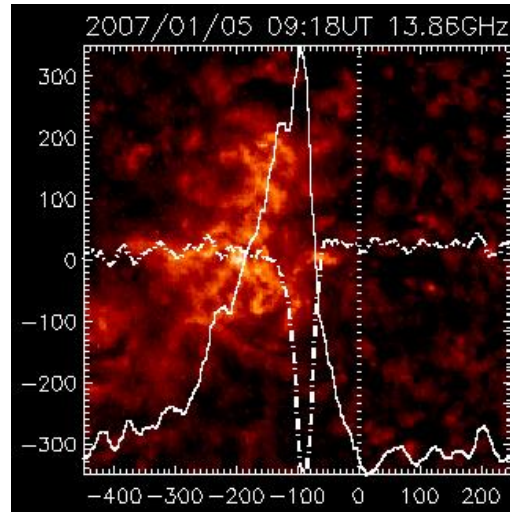
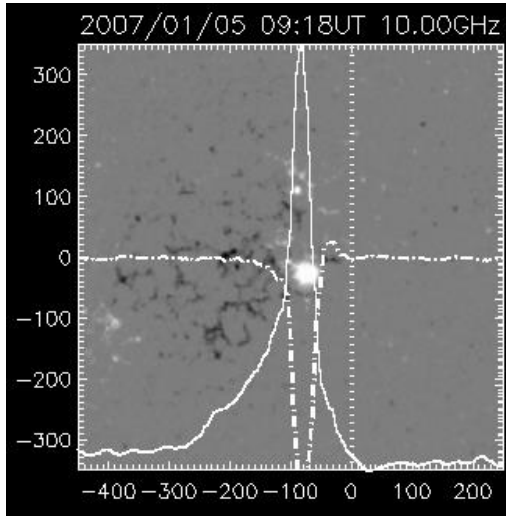
P% in max V



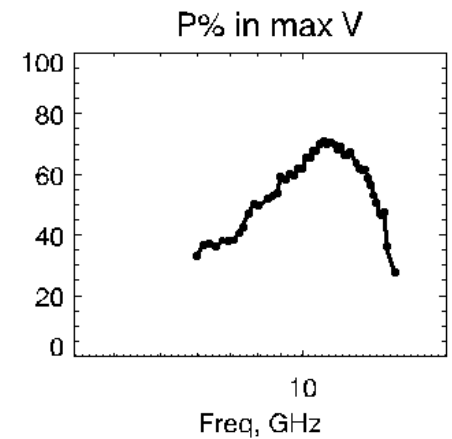
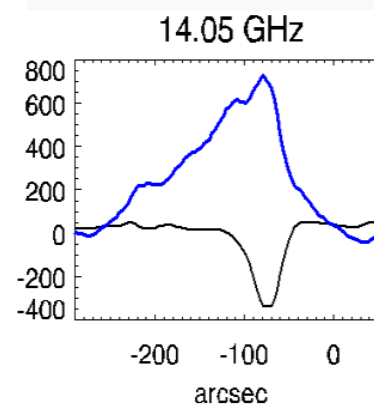
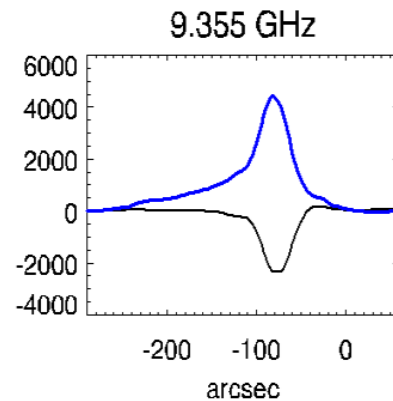
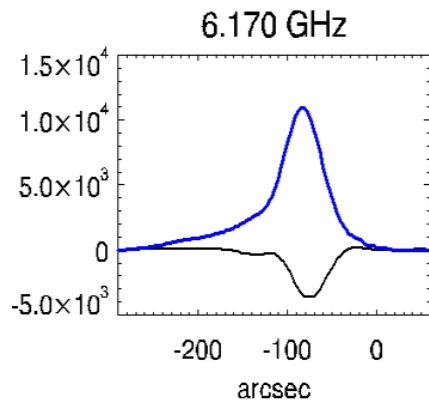
Magnetosphere with a Sunspot and a complex plage

05 Jan
2007

AR
10933



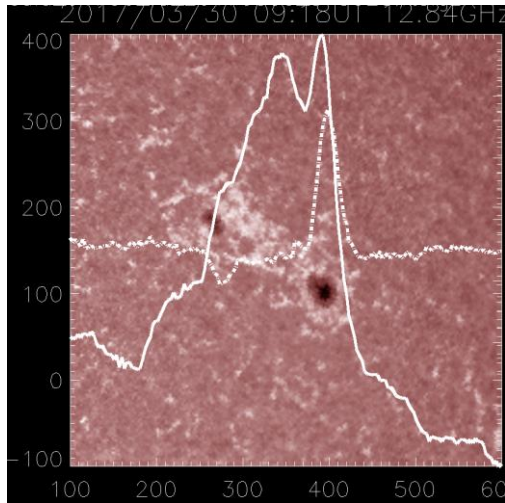
Magnetogram MDI, 10 GHz 304 A, 14 GHz



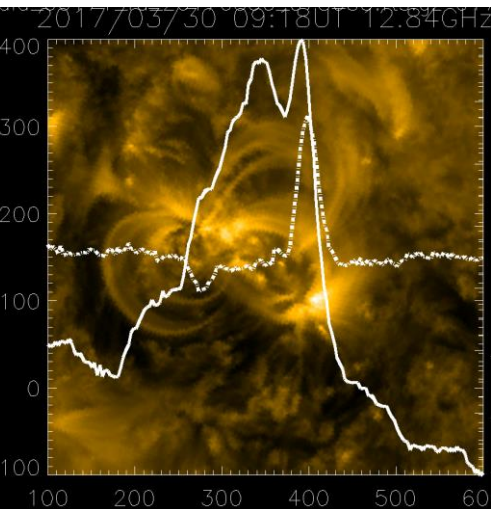
Magnetosphere with a strong Halo + Sunspot component

30 Mar
2017

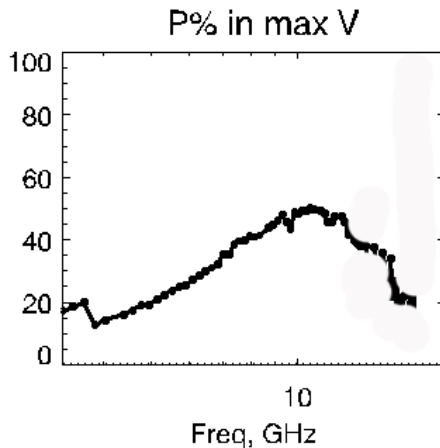
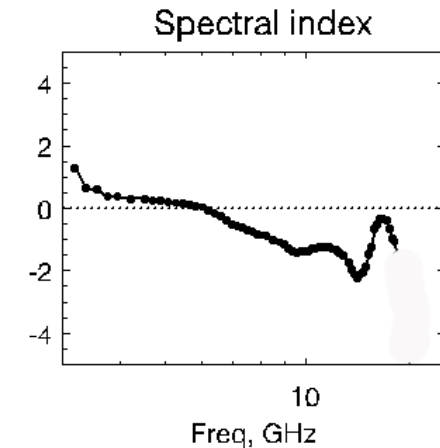
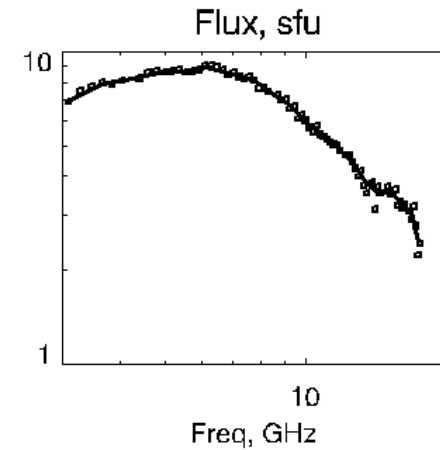
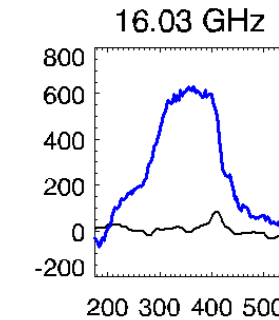
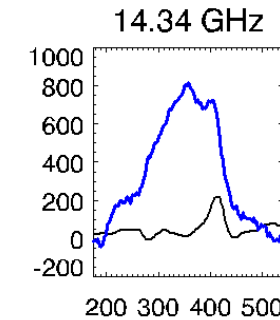
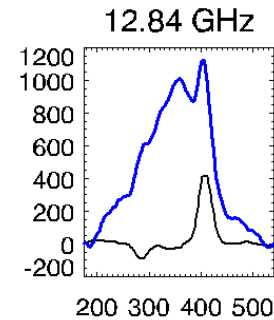
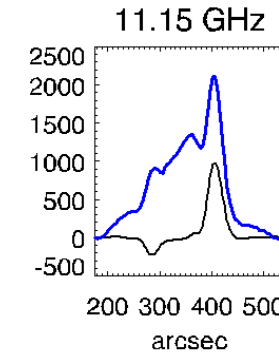
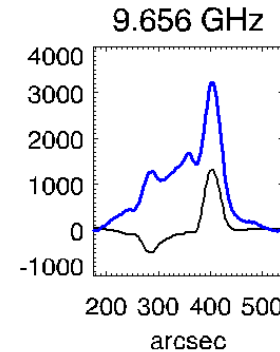
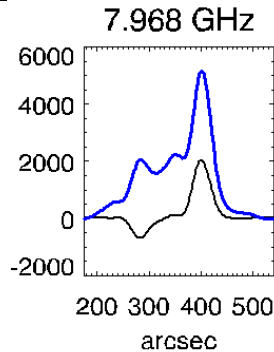
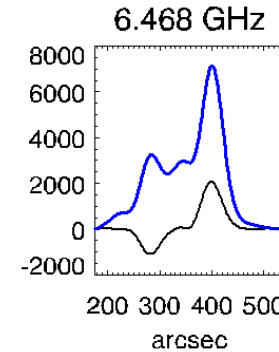
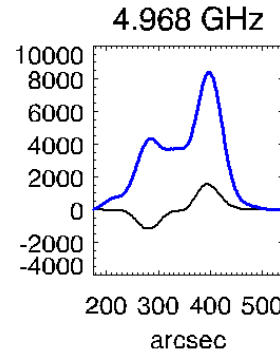
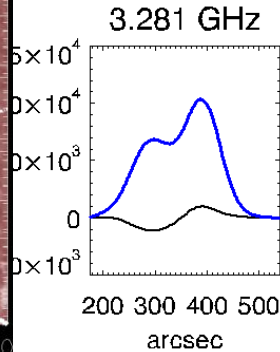
AR
12644



1700 A, 13 GHz



171 A, 13 GHz



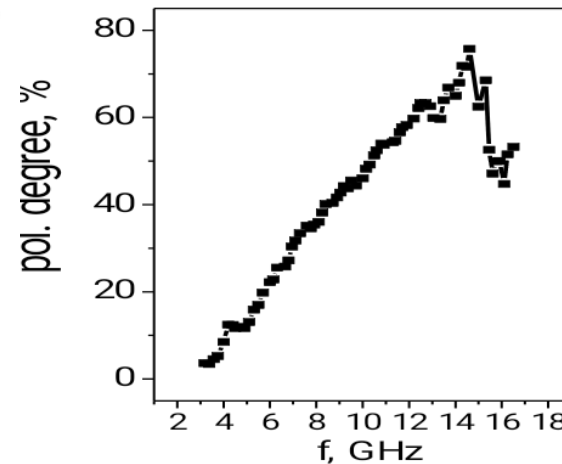
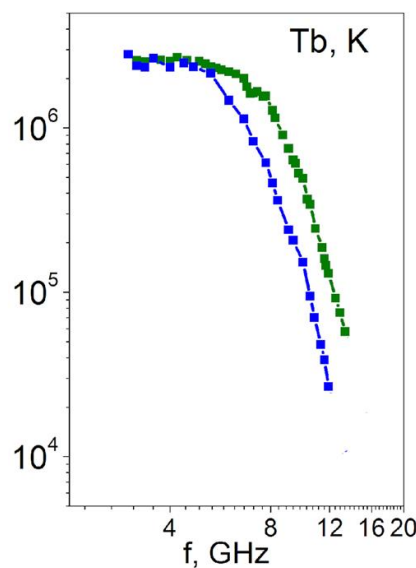
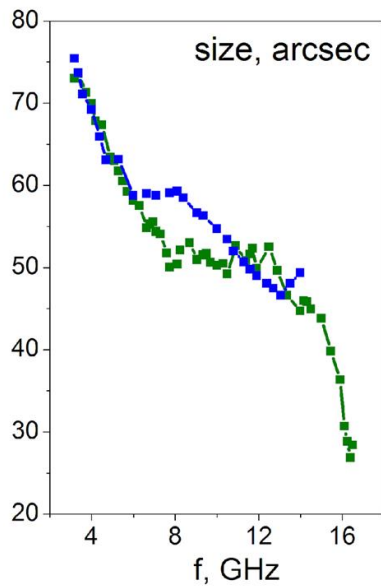
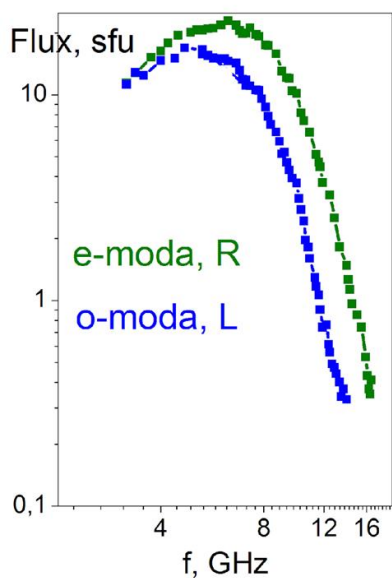
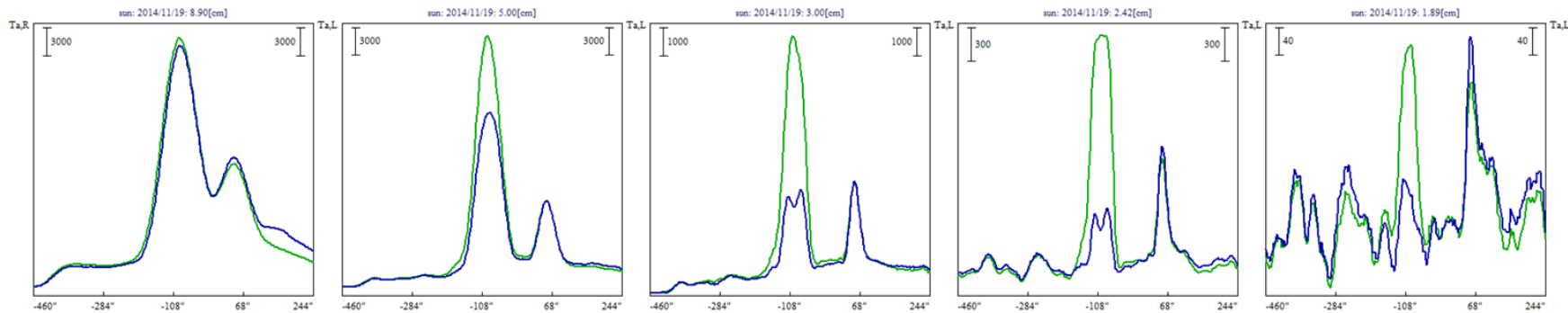
3.4 GHz

6.0 GHz

15.0 GHz

12.5 GHz

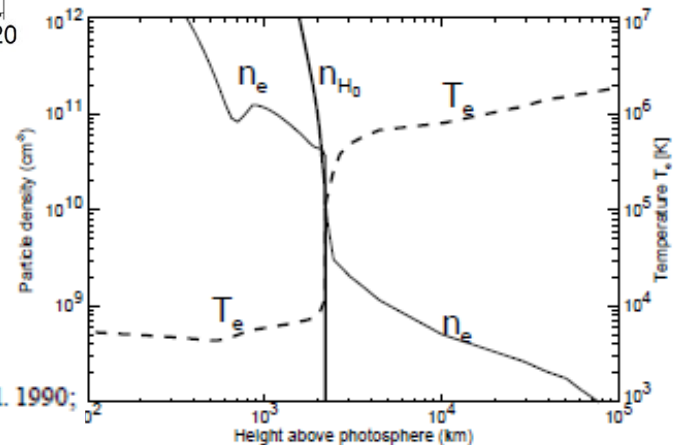
15.8GHz



AR 12209

19 Nov 2014

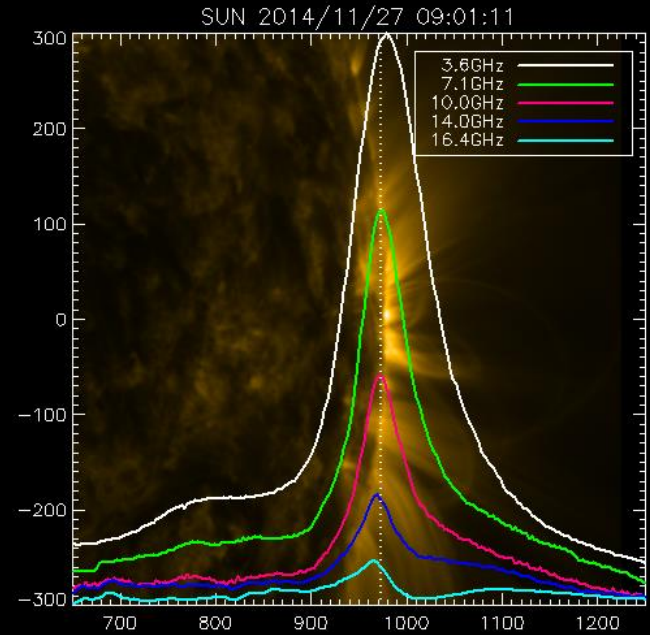
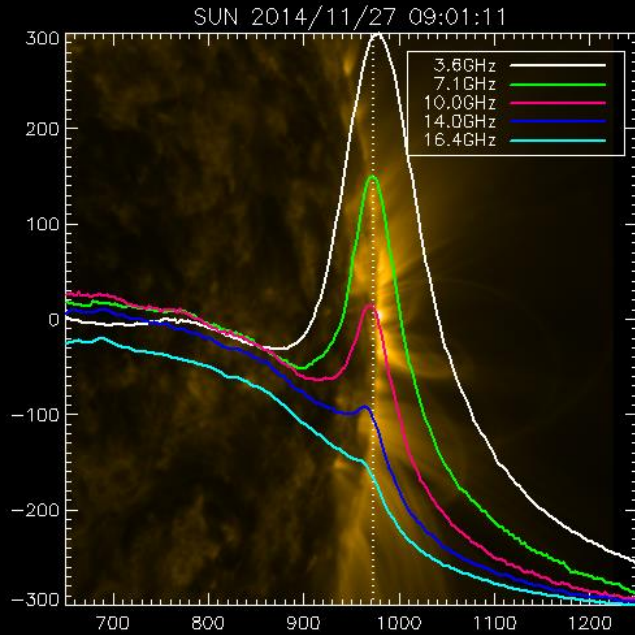
Electron density and temperature model of the chromosphere (Fontenla et al. 1990;
Model FAL-C) and lower corona (Gabriel, 1976).



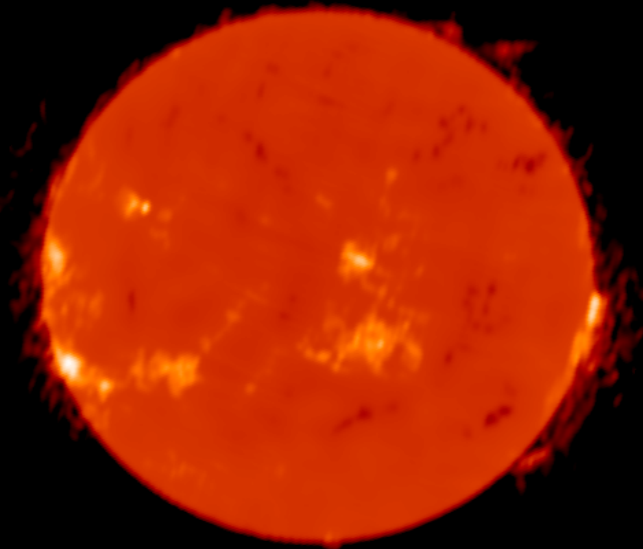
Spot source and high arcade of loops on the limb

saia_00171_fd_20141127_082959

saia_00171_fd_20141127_082959

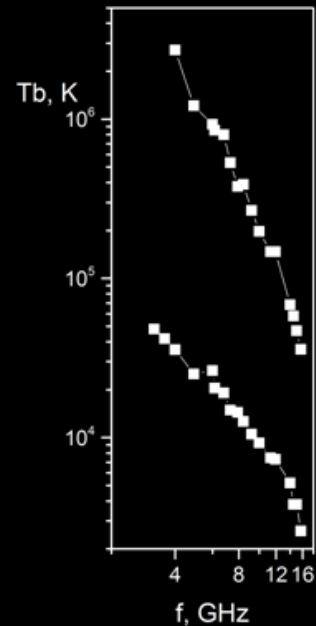


NOBEYAMA RADIO HELIOGRAPH 17GHz (R+L)



2014-11-27 02:44:34.136

SOLAR NORTH IS UP
 CENTER
 (257 , 257)/ PIXEL
 PEAK
 60492 K
 PIXEL SIZE
 4.911 (ARCSEC)
 SOLAR RADIUS
 983.891 (ARCSEC)
 SOLAR POLAR ANGLE
 17.5833 (DEGREE)
 SOLAR B0
 1.4051 (DEGREE)
 DATA
 LOGSCALE
 MAX=1E4.8 : MIN=1E3



Spot source

arcade up to
 150 000 km

Comparison with data from other instruments in different ranges, visual identification of details.

1. Downloading (out: fits) :

RATAN-600

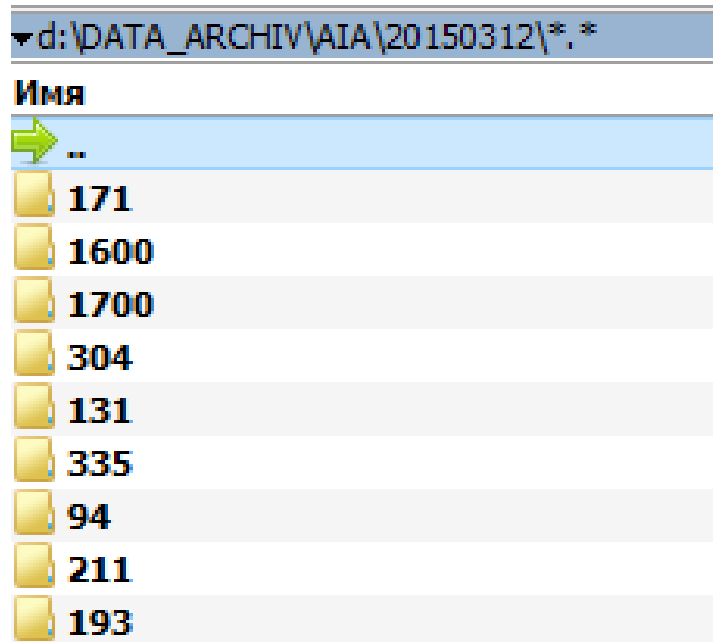
HMI and AIA

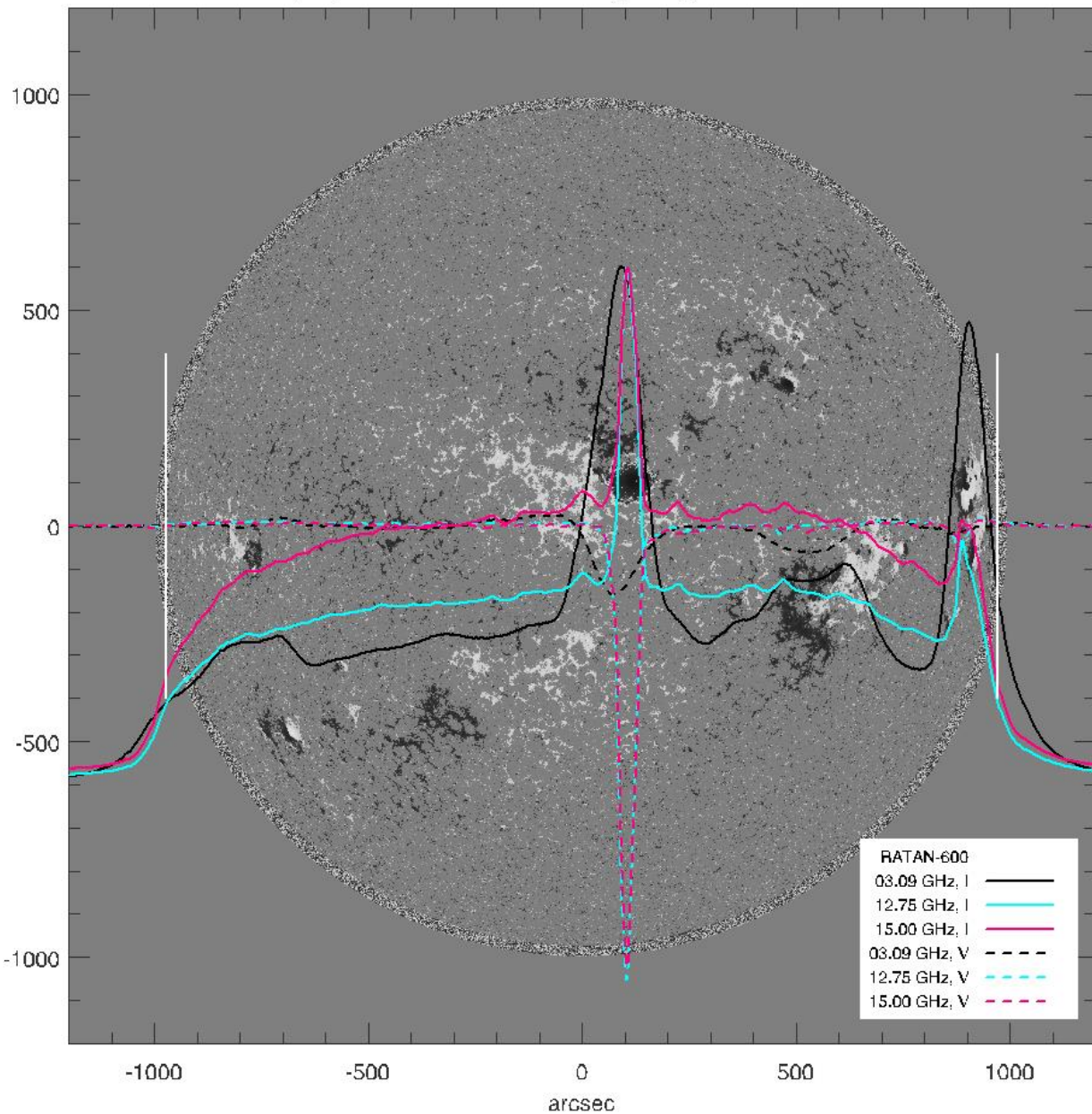
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az_list=['2015-03-12T12:10:00','2017-09-23T09:05:58']
```

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aia_utils_download_full_by_list, az_list, [171,131,304,171,1700], 'd:\DATA_ARCHIV\AIA\'
```

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```

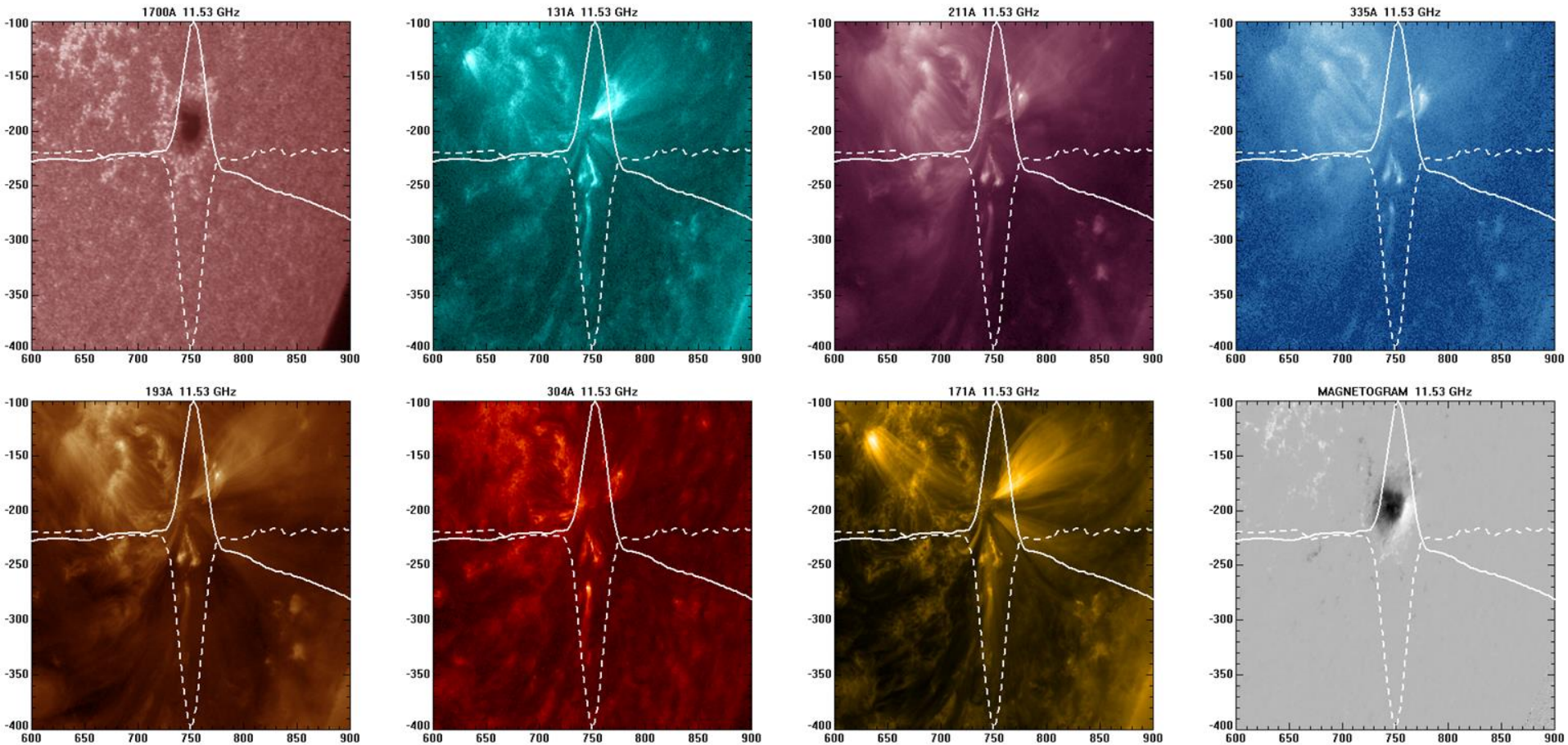
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rtu_download_ratan_fits, dates = ['20150312'], loc_dir = 'd:\DATA_ARCHIV\RATAN_fits\'
```





2019-04-17T08:15:01 -> 2019-04-17T08:59:25

The jet southward was seen multiple times from the western part of the big spot of AR 12738, probably reflecting long-lived coronal structures including open field lines



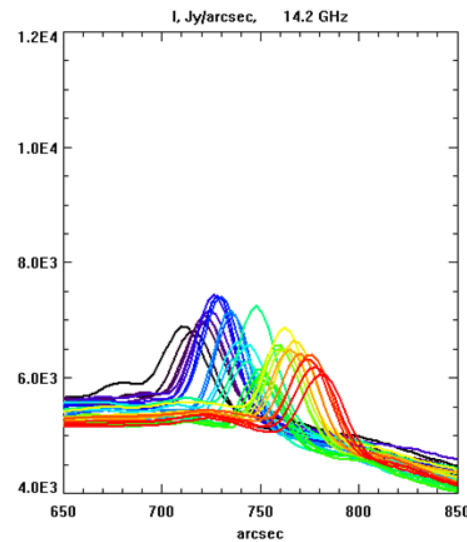
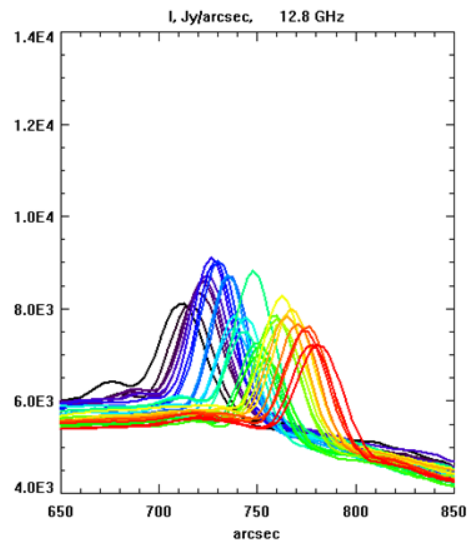
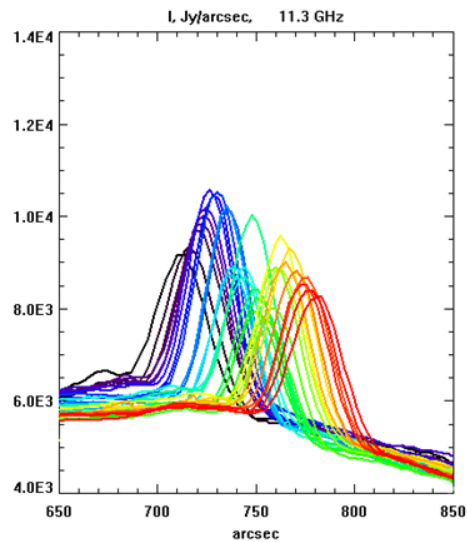
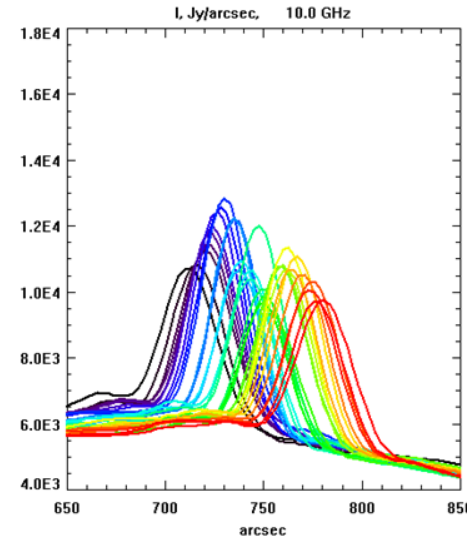
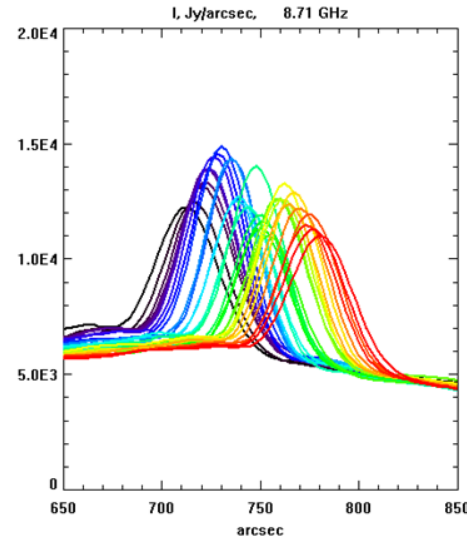
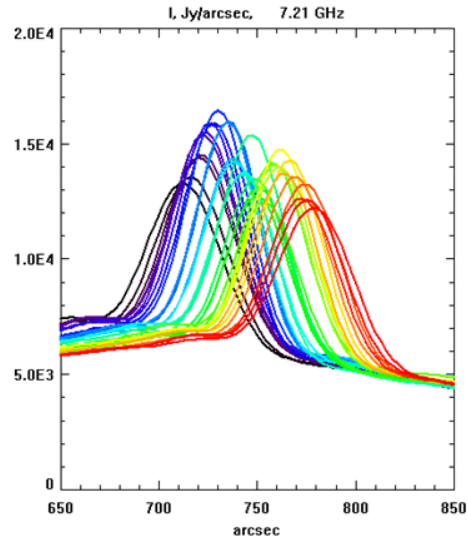
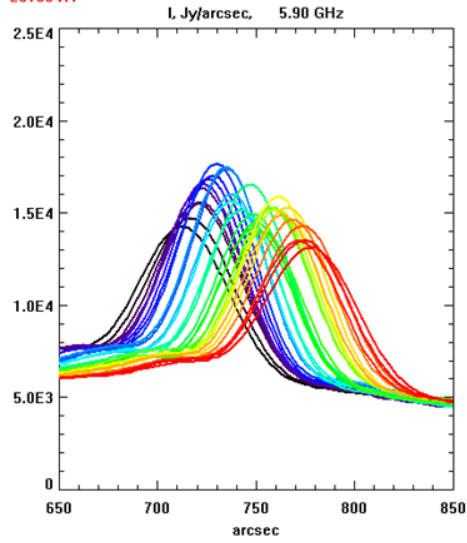
SDO + RATAN-600 (regular mode)

Spectral-polarization observations of the Sun in regular mode on RATAN-600 in 31 azimuths. Intensity.

2019-04-17

AR 12738

20190417



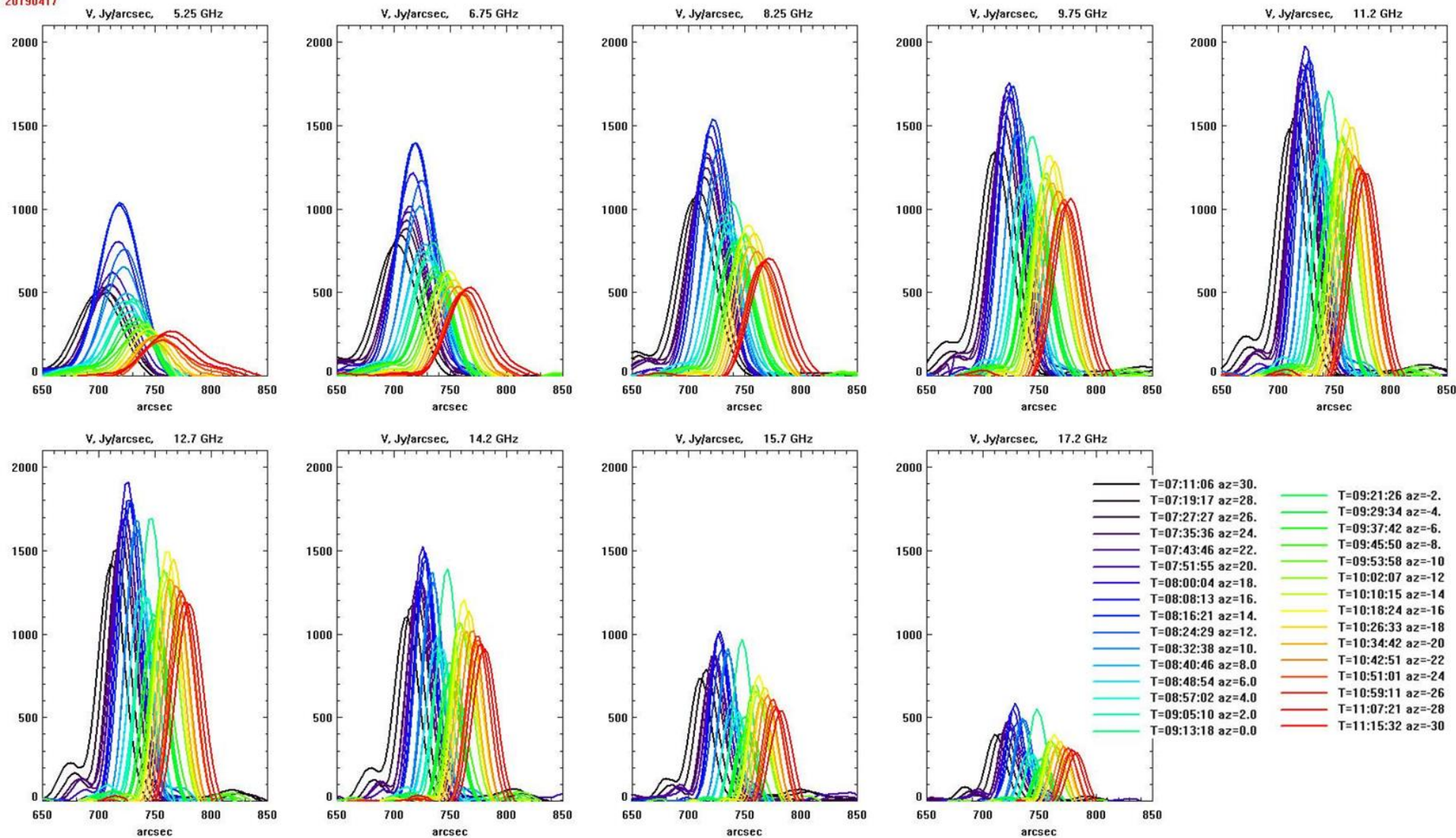
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- T=07:19:17 az=28.
- T=07:27:27 az=26.
- T=07:35:36 az=24.
- T=07:43:46 az=22.
- T=07:51:55 az=20.
- T=08:00:04 az=18.
- T=08:08:13 az=16.
- T=08:16:21 az=14.
- T=08:24:29 az=12.
- T=08:32:38 az=10.
- T=08:40:46 az=8.0.
- T=08:48:54 az=6.0.
- T=08:57:02 az=4.0.
- T=09:05:10 az=2.0.
- T=09:13:18 az=0.0.
- T=09:21:26 az=-2.
- T=09:29:34 az=-4.
- T=09:37:42 az=-6.
- T=09:45:50 az=-8.
- T=09:53:58 az=-10.
- T=10:02:07 az=-12.
- T=10:10:15 az=-14.
- T=10:18:24 az=-16.
- T=10:26:33 az=-18.
- T=10:34:42 az=-20.
- T=10:42:51 az=-22.
- T=10:51:01 az=-24.
- T=10:59:11 az=-26.
- T=11:07:21 az=-28.
- T=11:15:32 az=-30.

Spectral-polarization observations of the Sun in regular mode on RATAN-600 in 31 azimuths. Polarization.

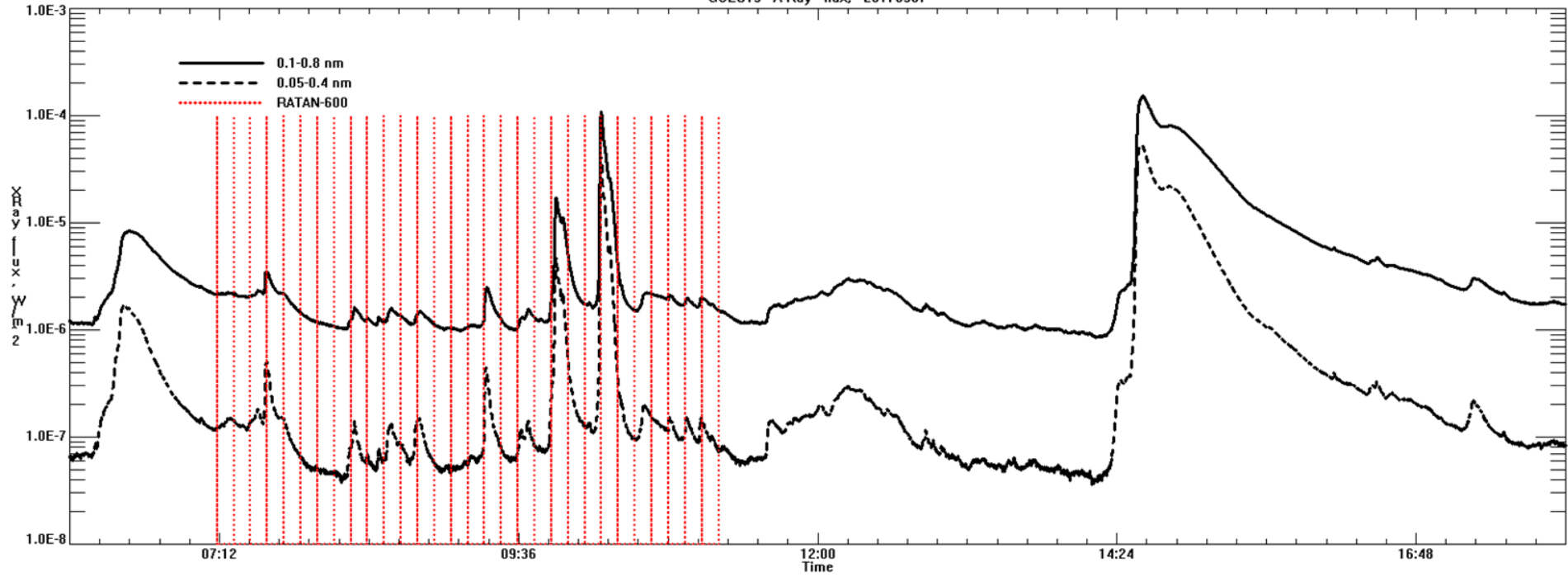
2019-04-17

AR 12738

20190417



GOES13 X-Ray flux, 20170907

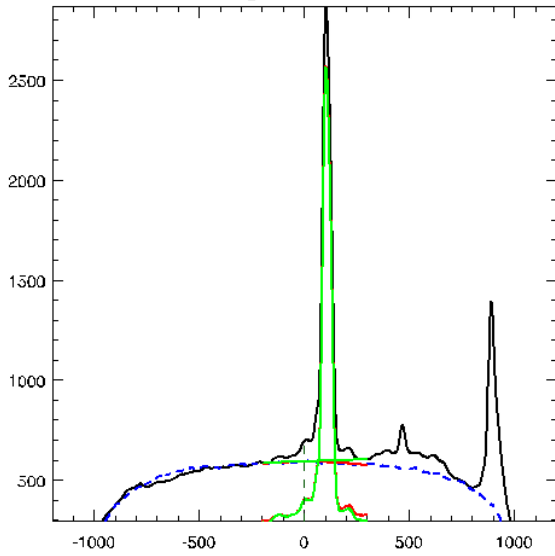


Calibration and background subtraction.

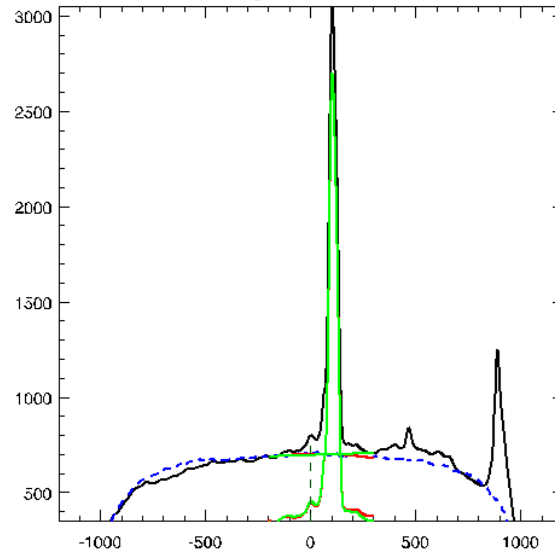
-approximation of the background of a quiet Sun inside the boundaries of AO

-creating a quiet Sun template

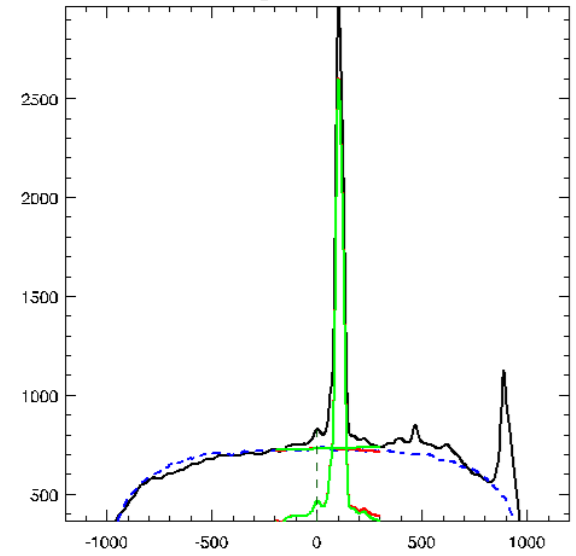
Right 9.700GHz



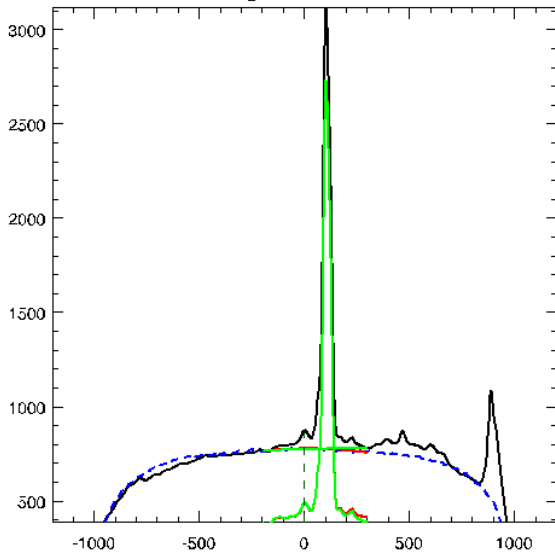
Right 11.30GHz



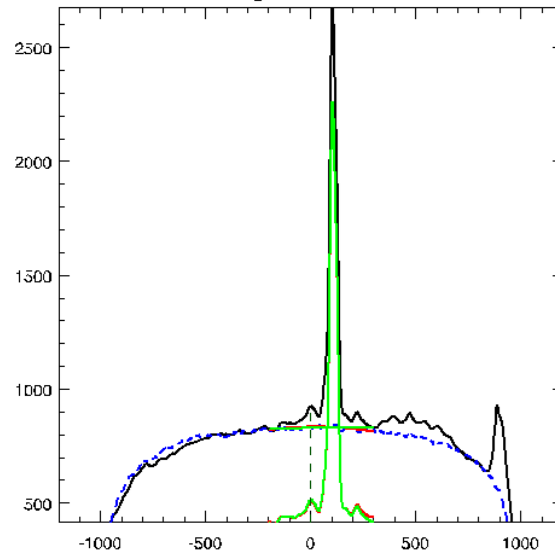
Right 11.90GHz



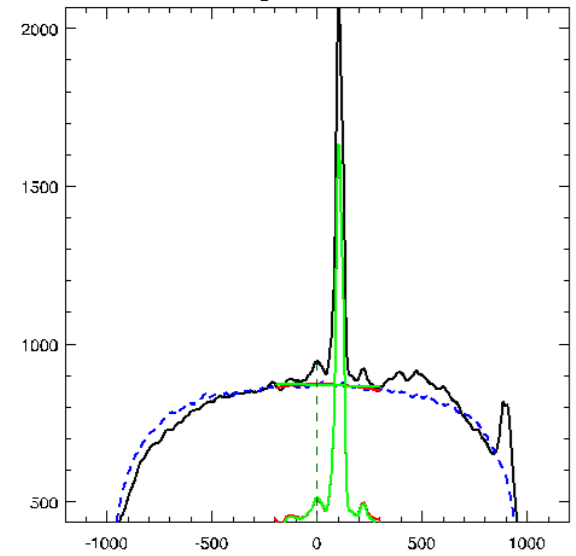
Right 12.70GHz



Right 14.30GHz



Right 15.75GHz

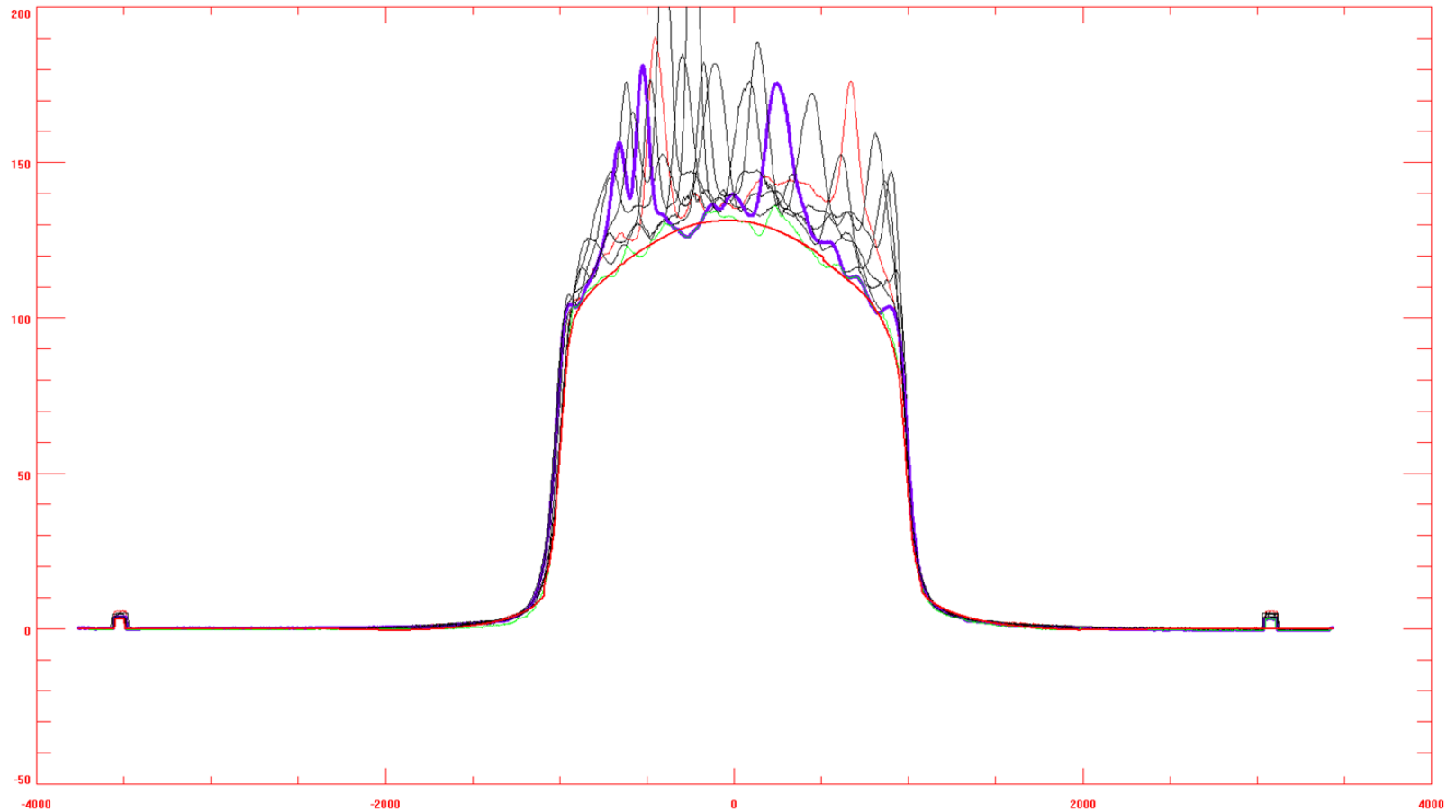


Quiet Sun level

Calibration and background subtraction.

-approximation of the background of a quiet Sun inside the boundaries of AO

-creating a quiet Sun template

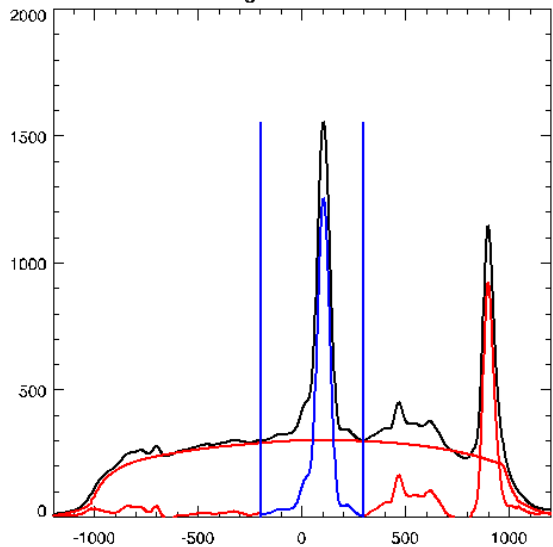


Calibration and background subtraction.

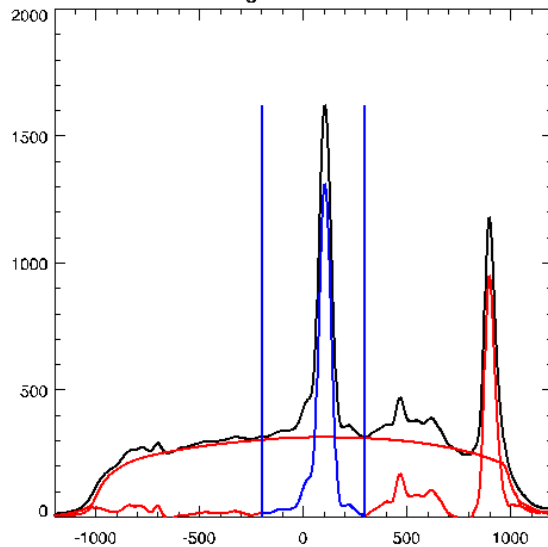
-approximation of the background of a quiet Sun inside the boundaries of AO

-creating a quiet Sun template

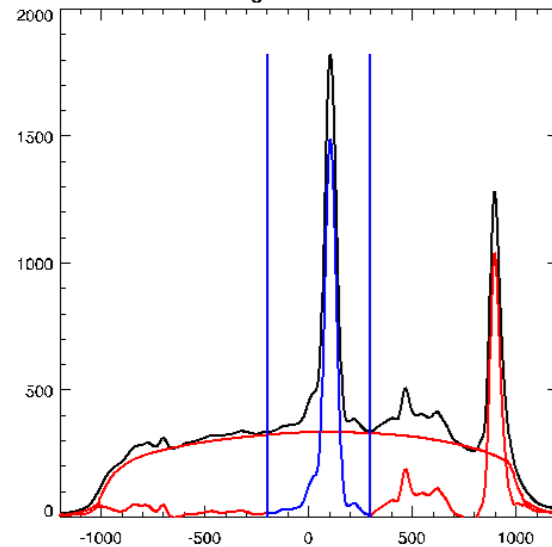
Right 5.500GHz



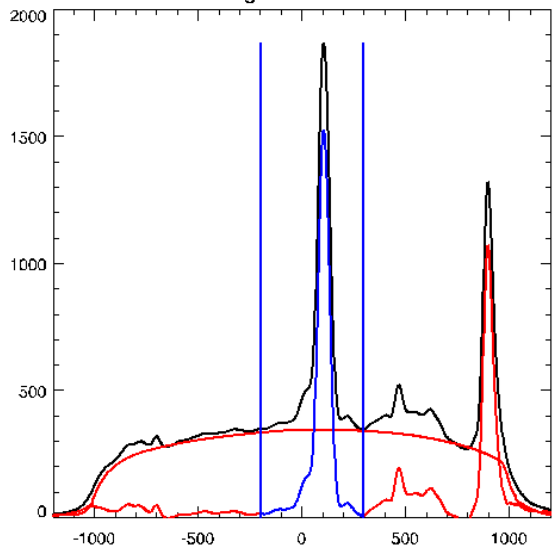
Right 5.700GHz



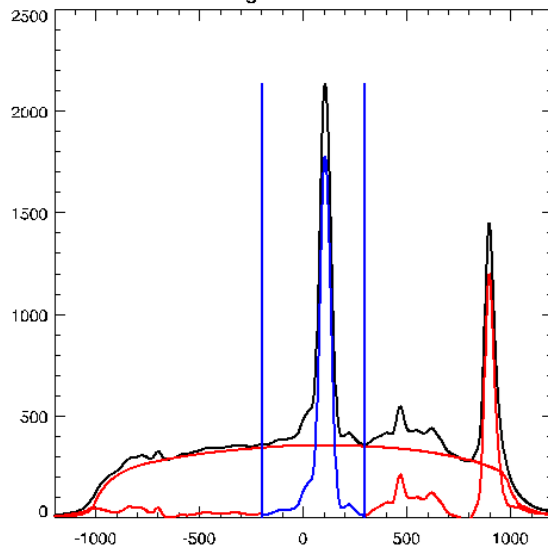
Right 6.000GHz



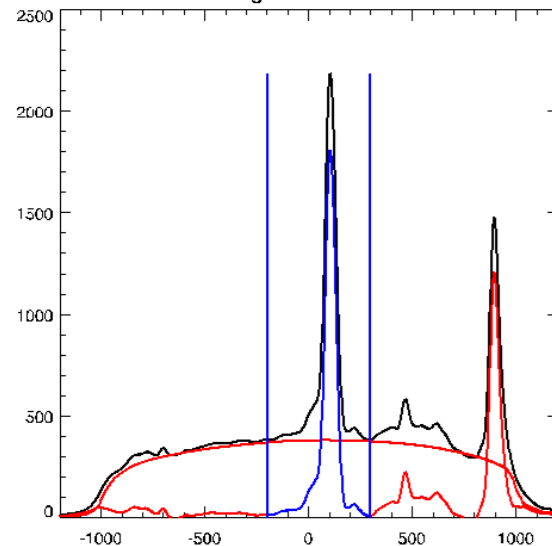
Right 6.150GHz



Right 6.300GHz

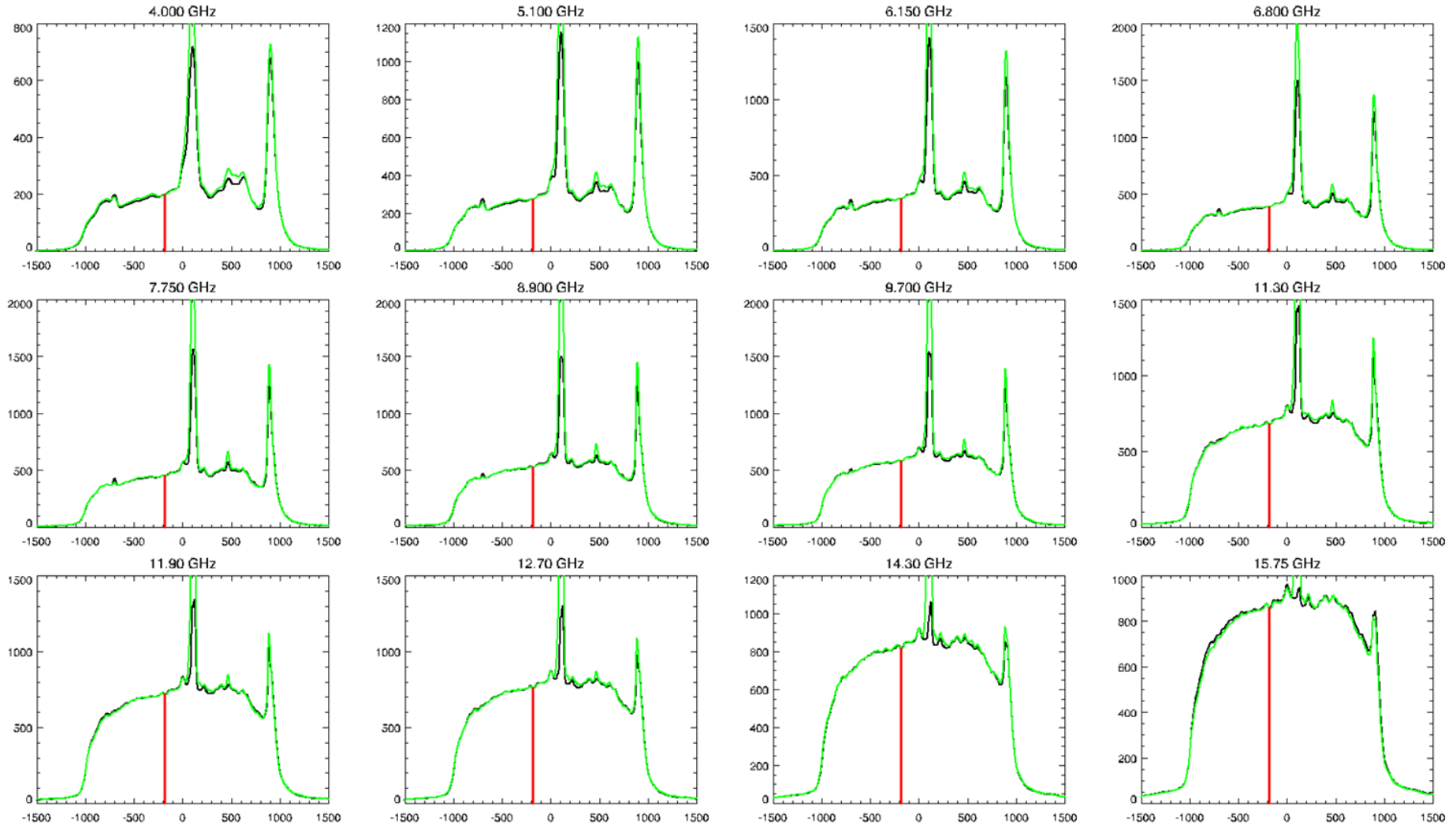


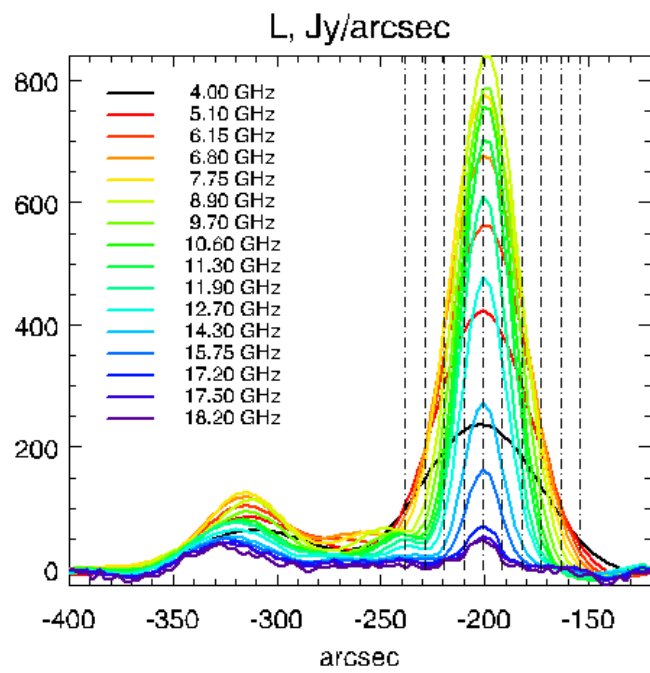
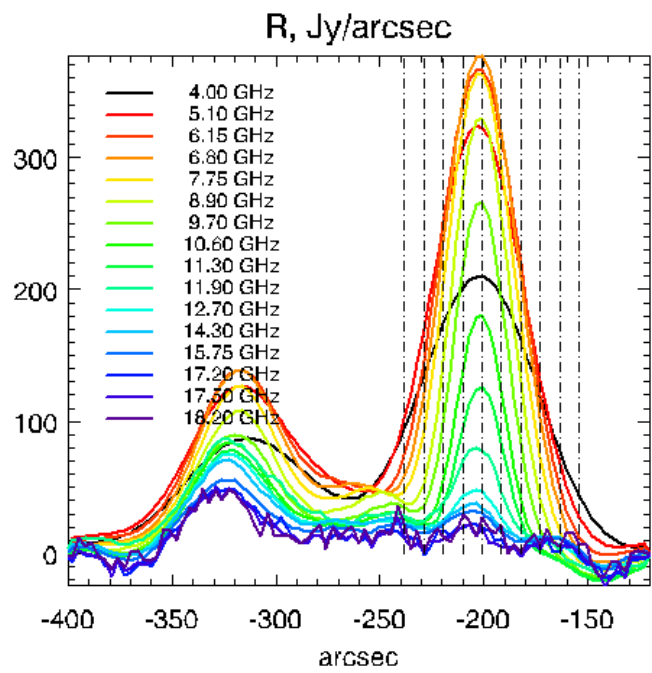
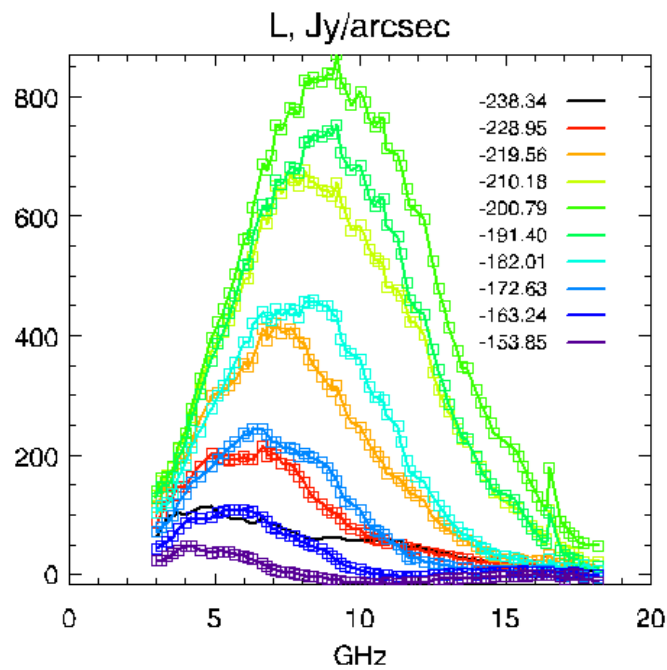
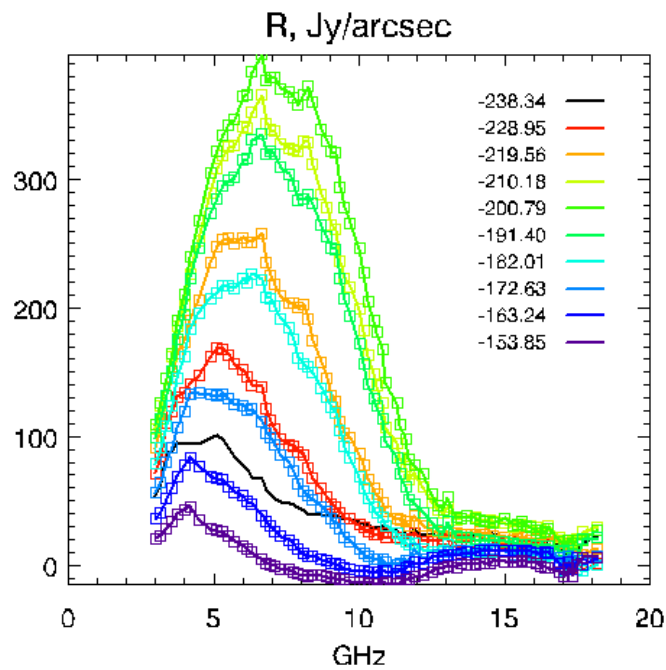
Right 6.650GHz



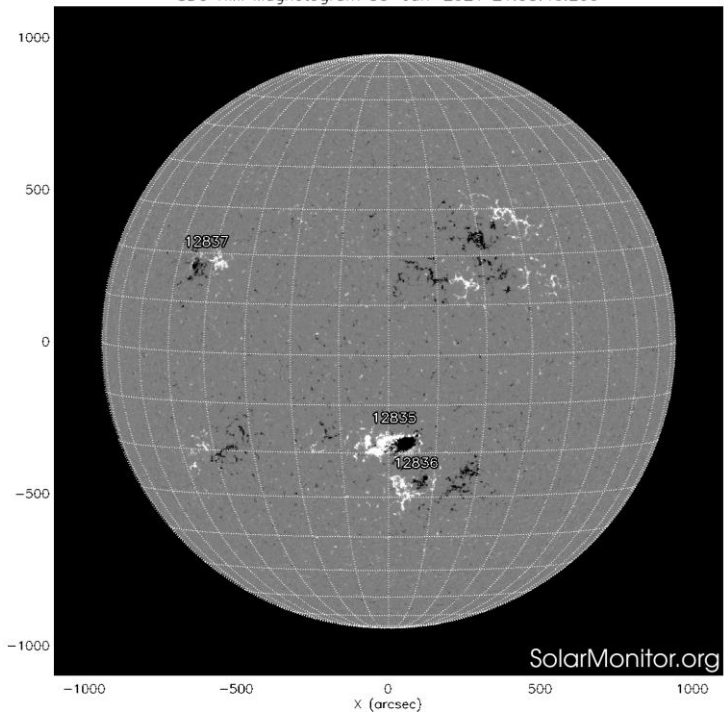
Calibration and background subtraction.

- approximation of the background of a quiet Sun inside the boundaries of AO
- creating a quiet Sun template

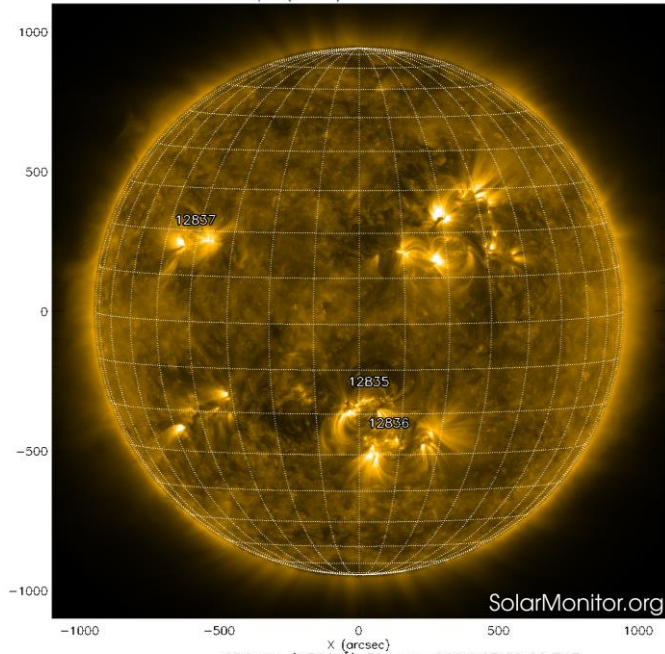




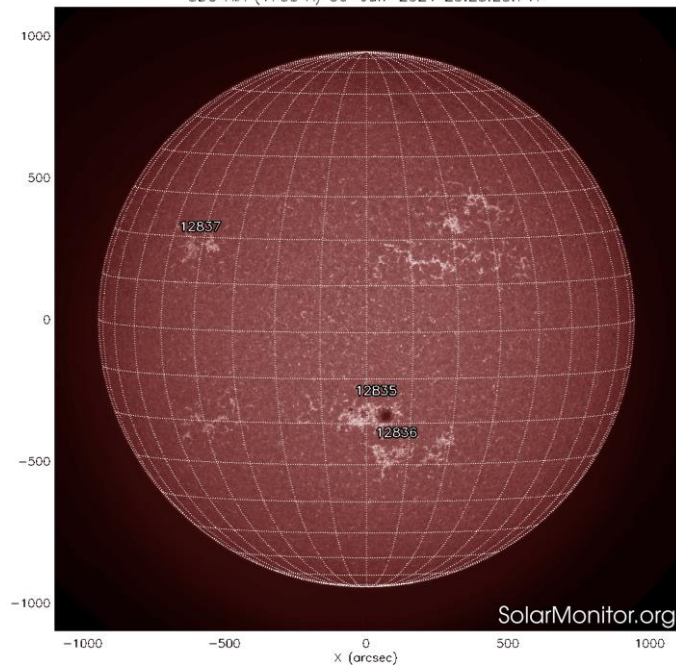
SDO HMI Magnetogram 30-Jun-2021 21:58:46.200



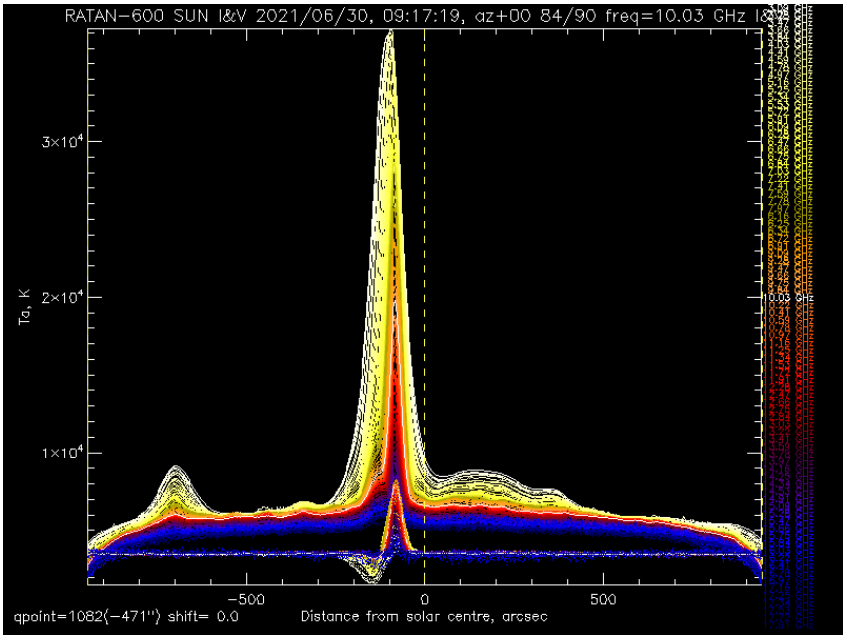
SDO AIA Fe IX/X (171 Å) 30-Jun-2021 23:25:09.350



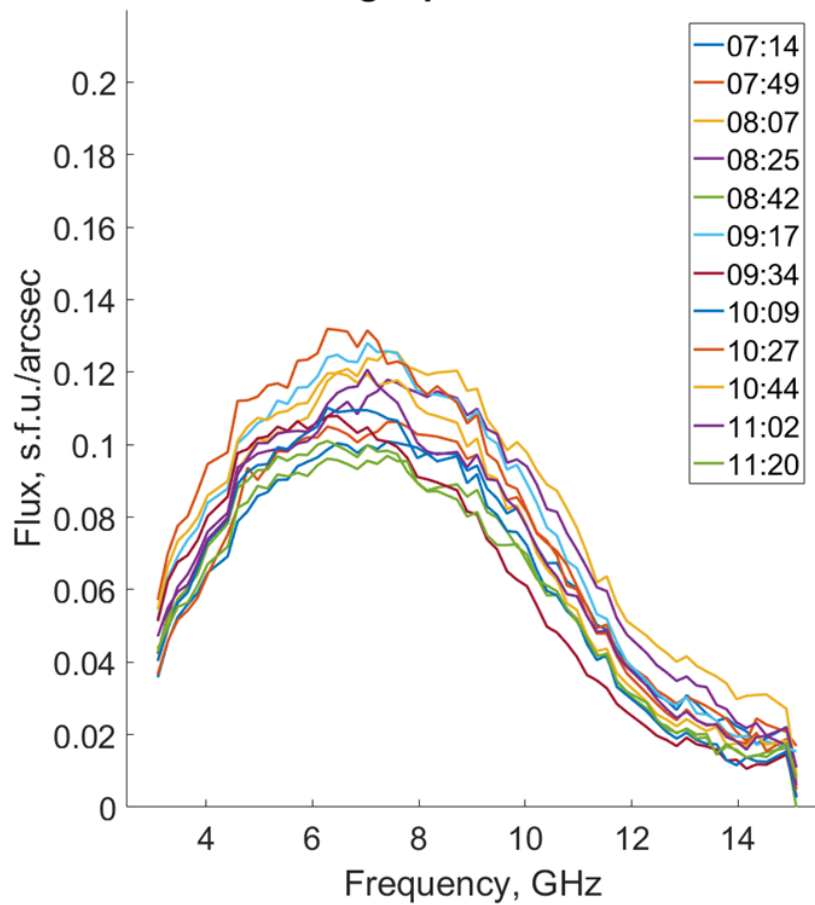
SDO AIA (1700 Å) 30-Jun-2021 23:28:28.717



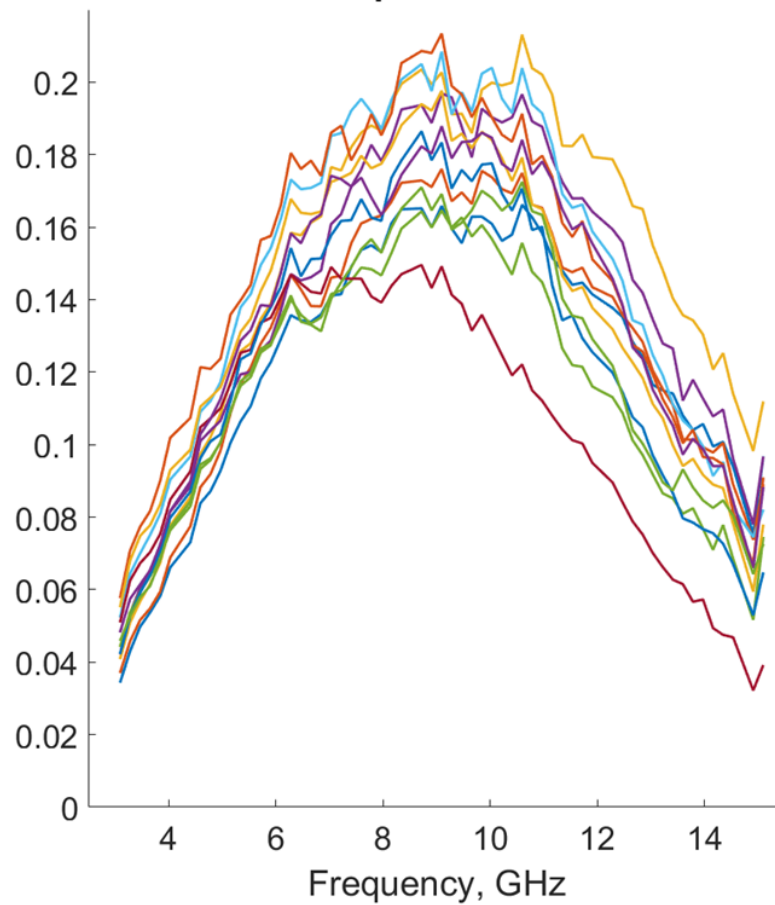
RATAN-600 SUN l&v 2021/06/30, 09:17:19, az+00 84/90 freq=10.03 GHz 18.2



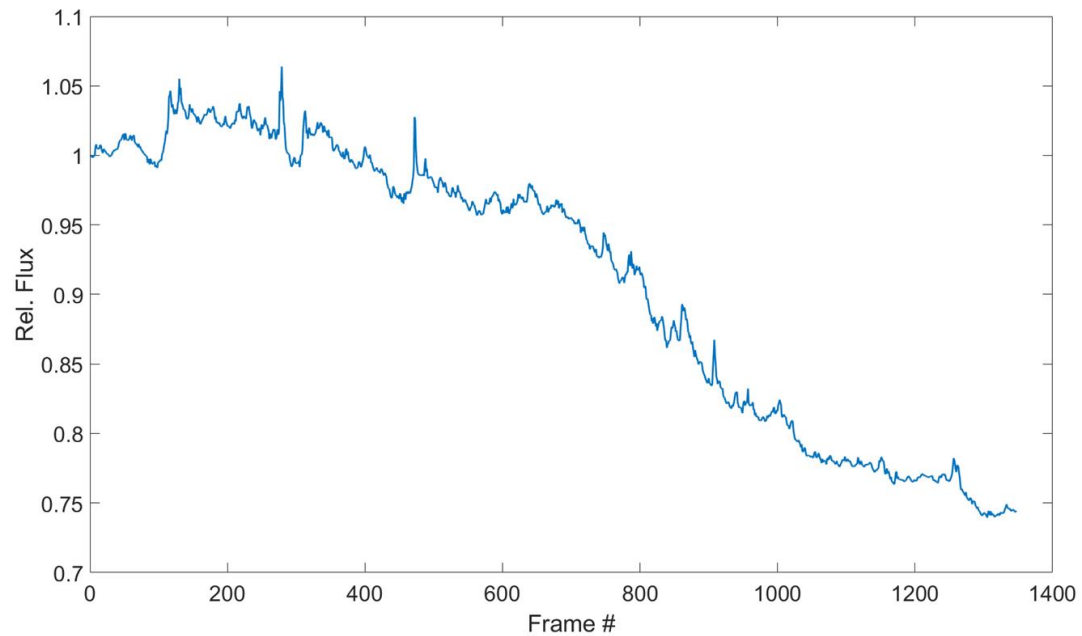
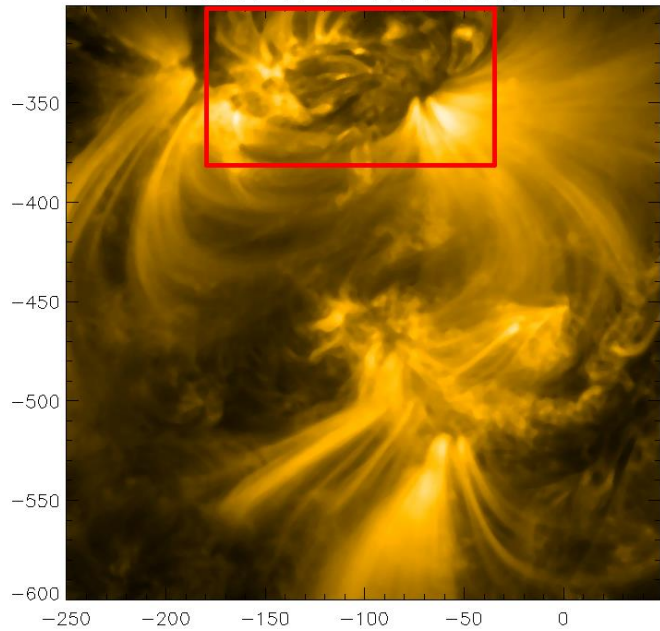
Right polarization



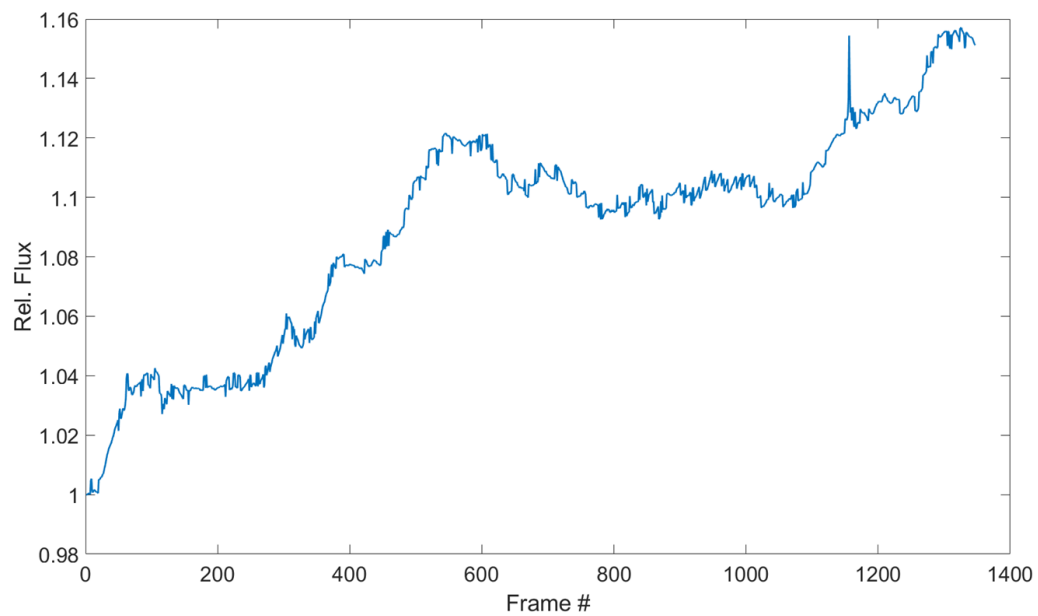
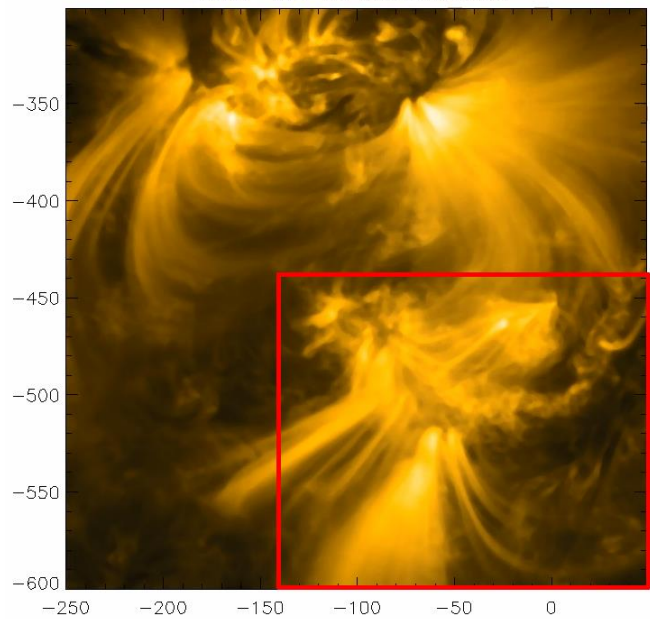
Left polarization

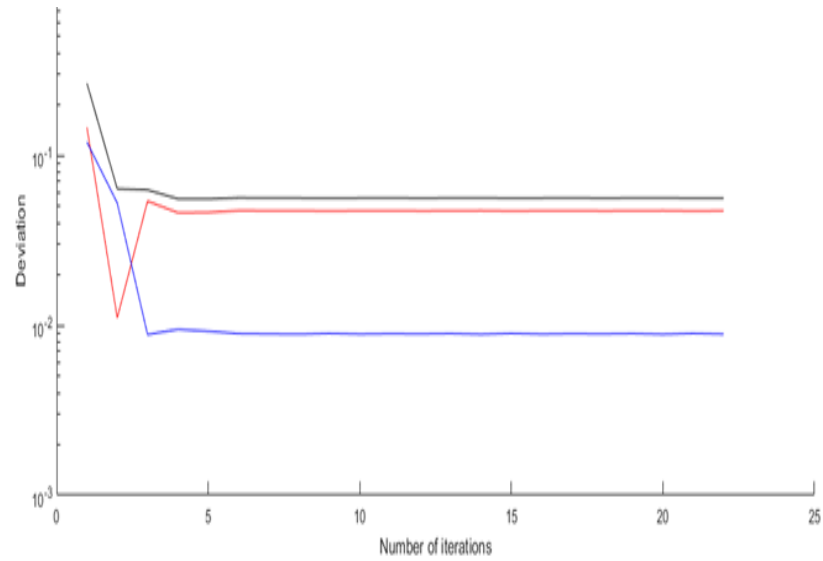
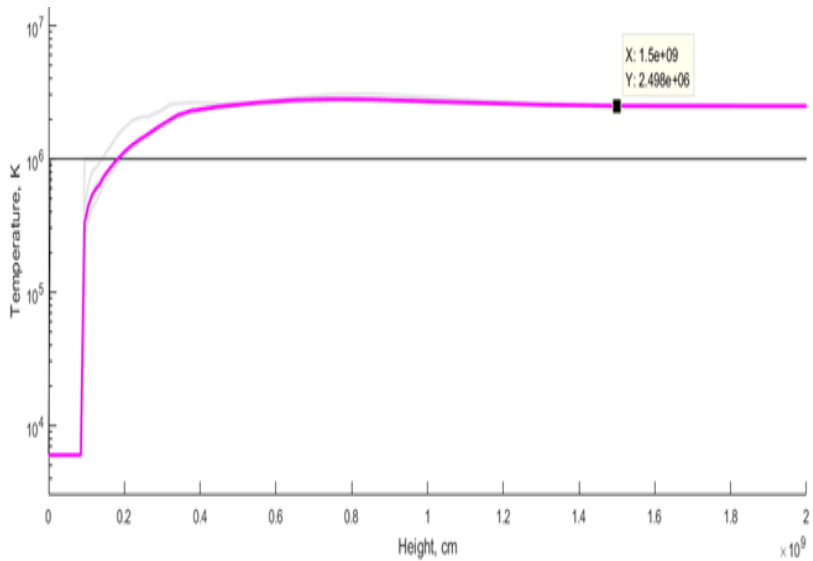


2021-06-30 07:00:10.350

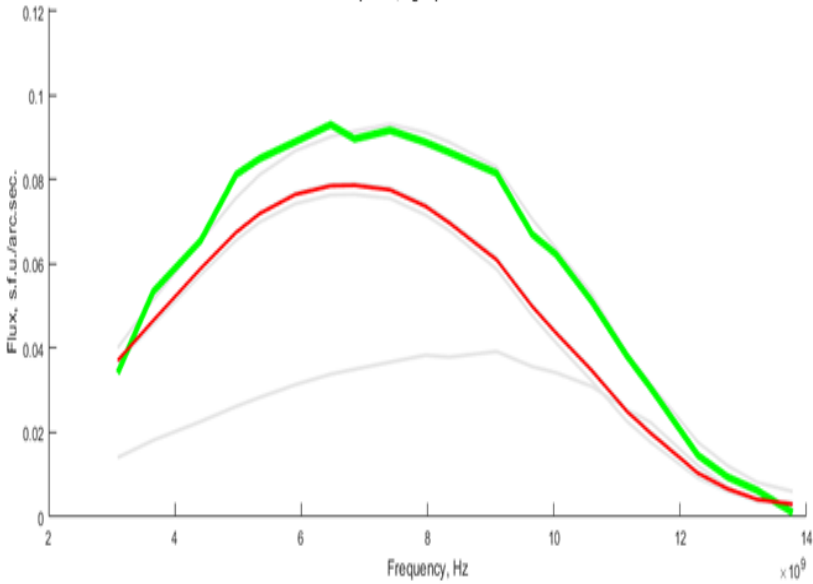


2021-06-30 07:02:22.347

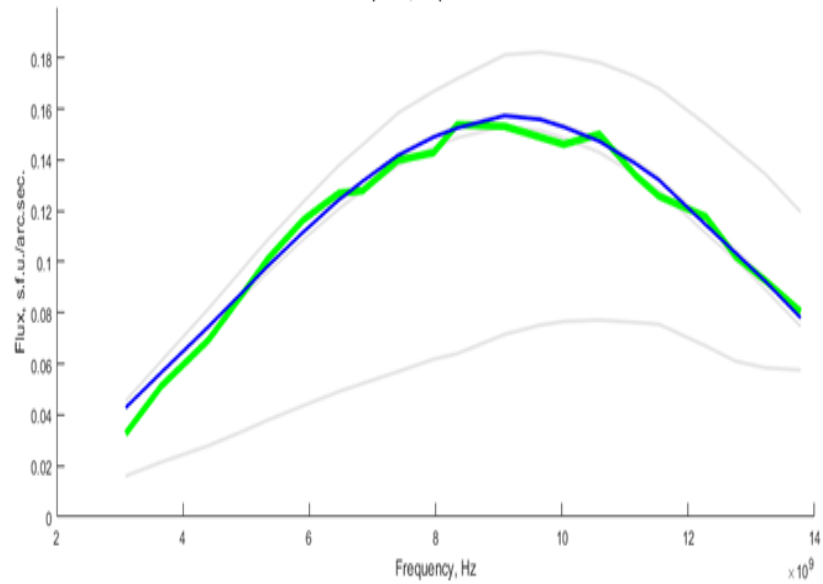


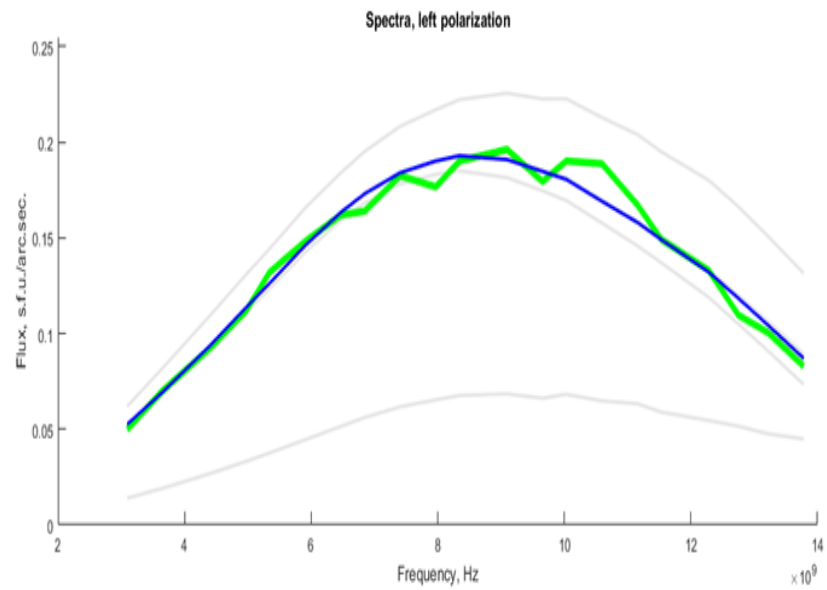
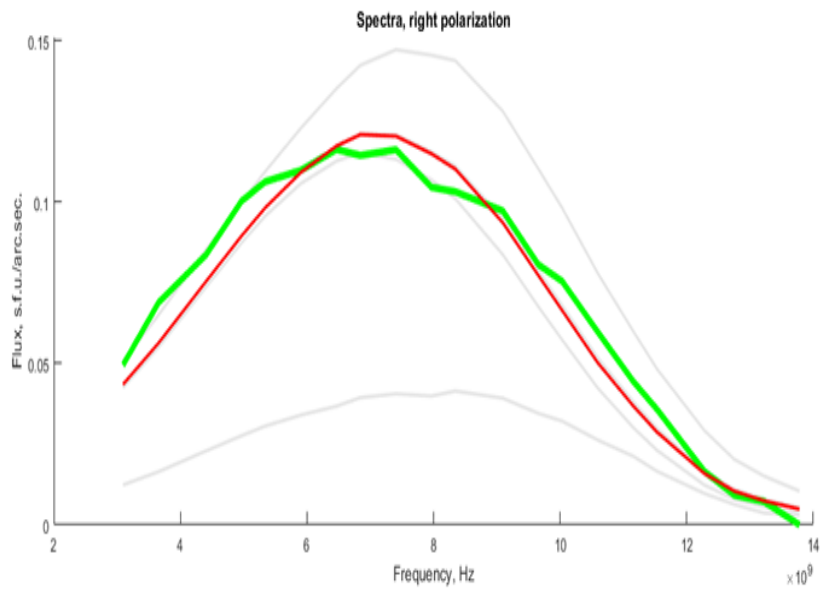


Spectra, right polarization

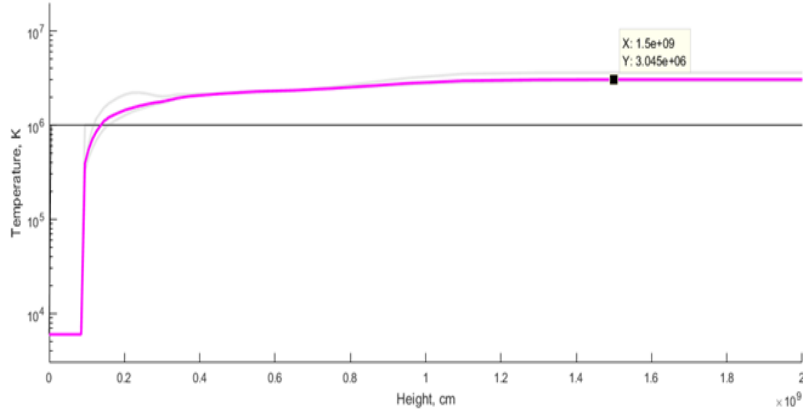


Spectra, left polarization

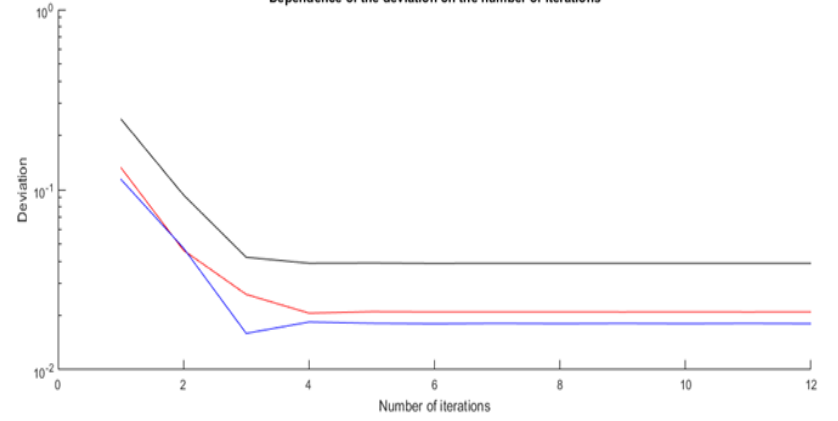




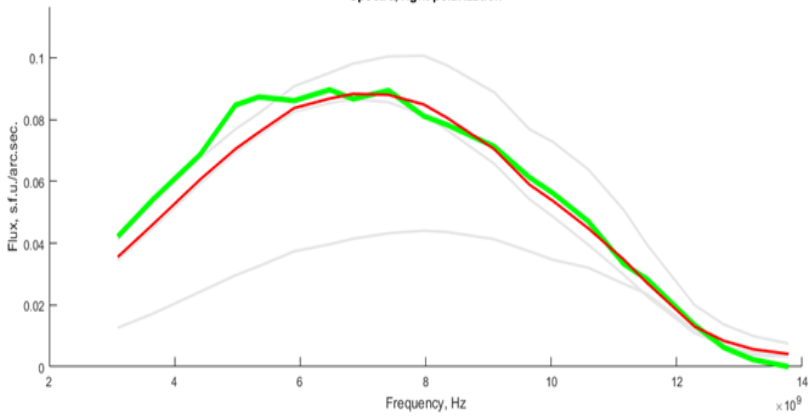
Height-temperature profile



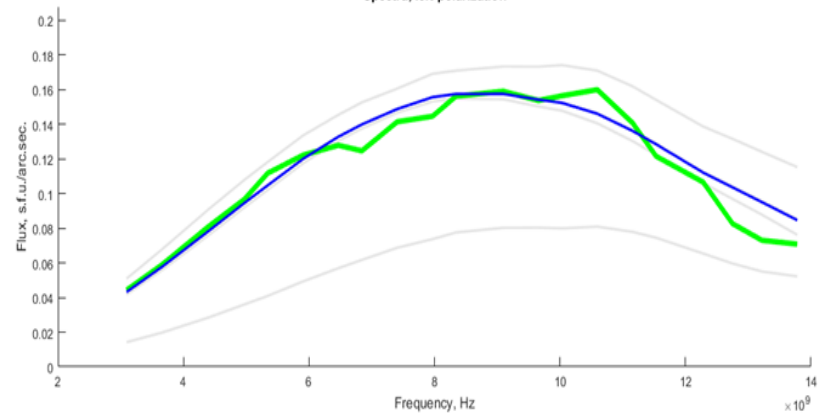
Dependence of the deviation on the number of iterations



Spectra, right polarization



Spectra, left polarization



RECEIVING EQUIPMENT OF THE NEW SPECTRAL COMPLEX, 1-3 GHz

Spectral polarization: 122 kHz (10^{-5})

Number of frequency channels: 8196/ GHz x2

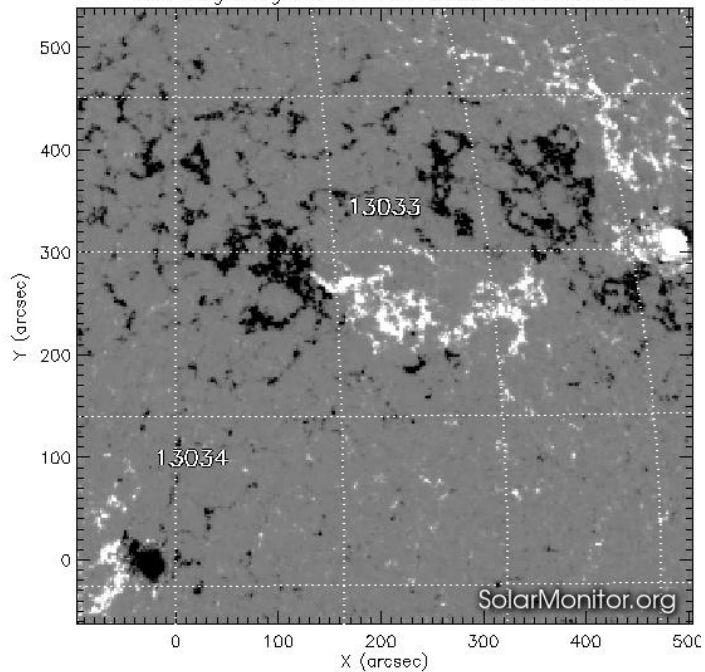
Temporal resolution: 8 ms/spectrum.

The temperature of the input noise of the equipment is from 100 K to 300 K, depending on the frequency (on laboratory stands).

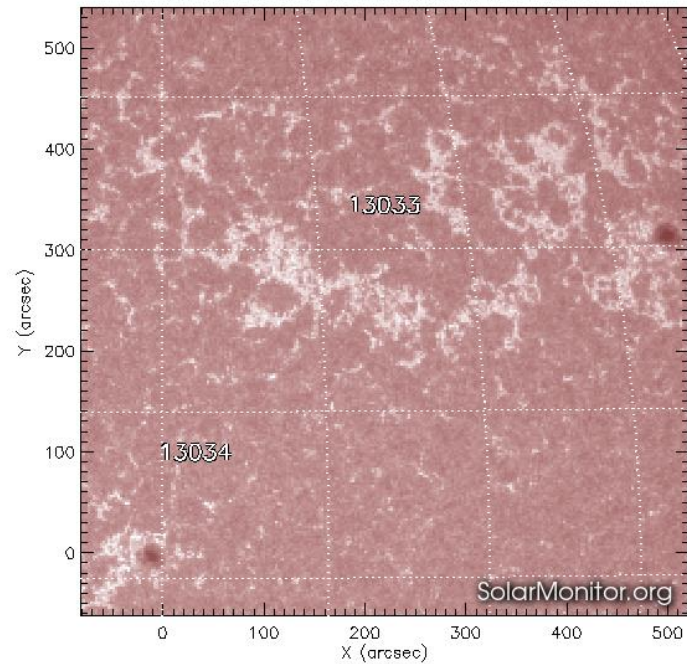
Dynamic range (including automation) – 90 dB.

*Storozhenko, A. ; Bogod, V. ; Shlenzin, S. ; Pervakov, A. ;
Ripak, A. ; Khaikin, V. ; Lebedev, M. ; Ovchinnikova, N.*

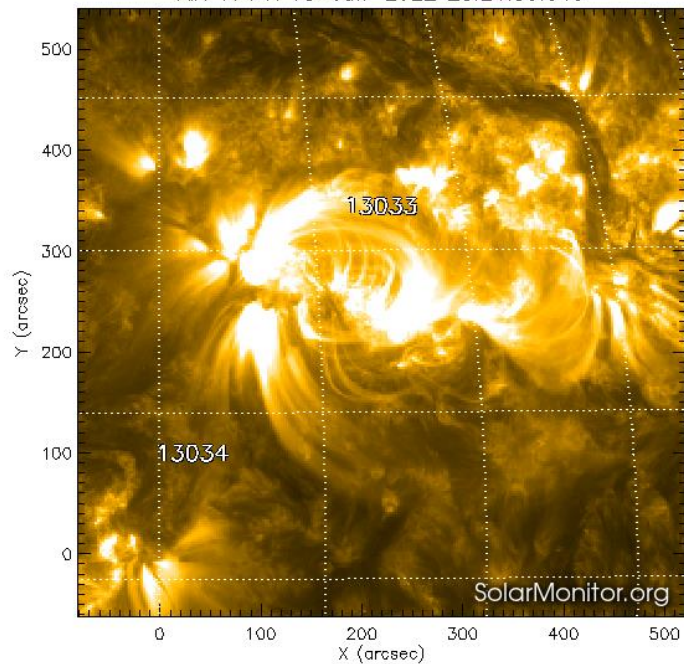
HMI Magnetogram 18-Jun-2022 21:58:45.900



AIA 1700 Å 18-Jun-2022 23:28:28.750



AIA 174 Å 18-Jun-2022 23:24:33.343



AIA 304 Å 18-Jun-2022 23:24:29.129

