

Information system for testing the Tanaka-Enome criterion and forecasting the solar activity based on microwave observations

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- **Pre-flare diagnostic**

- Statistical study revealed an existence of special features of flare-productive ARs. The regular and broadband RATAN-600 observations are very convenient for the daily analysis and diagnostic of the pre-flare plasma. Now the web applications for the such automatic diagnostic are under development.

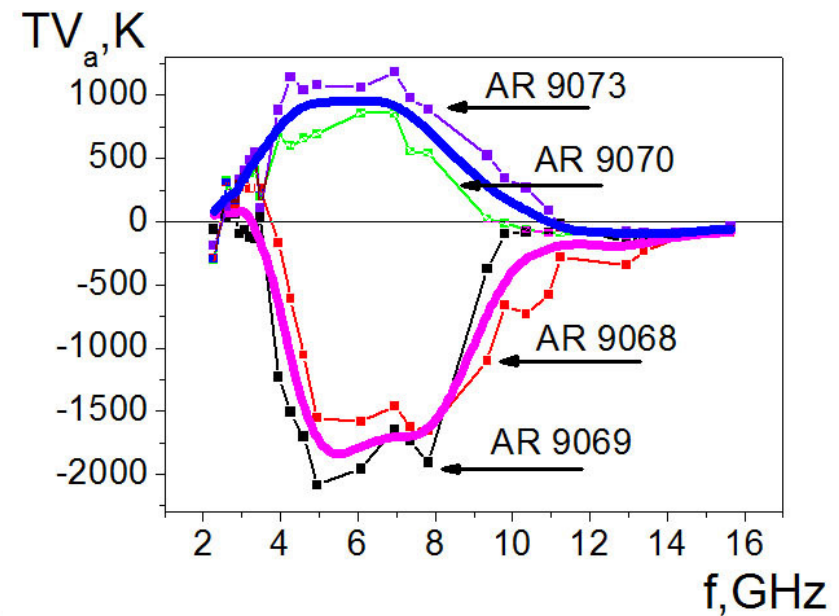
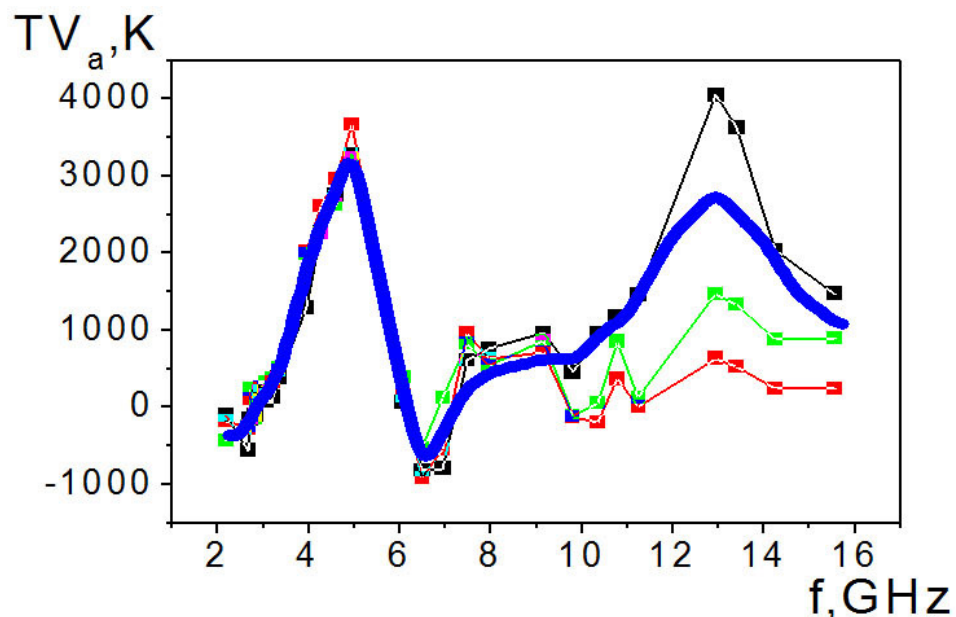
- V. M. Bogod and S.Kh.Tokhchukova, *Astronomy Letters*, 2003, 29,4,p.263.
- V. M. Bogod and S.Kh.Tokhchukova, *Cosmic Research*, 2006, 44,6,p.506

Last years the various unusual spectra of solar flare productive active regions were discovered by radio telescope RATAN-600 in 2 – 16 GHz frequency range.

- RATAN-600 spectral and polarization observations of the Sun at microwave frequencies resulted in the discovery of burst-productive active regions generating powerful events corresponding to levels M and X of X-ray emission.
- These regions are characterized by abrupt inversions of circular polarization at centimeter-wave frequencies in terms of frequency and time on the interval from several hours to three days.
- The studies performed are indicative of the existence of a prior prolonged phase in the preburst emission of active regions.
- Various peculiarities of the preburst centimeter-wave emission of the active region have been found. These effects show up mostly in the wavelength interval from 2 to 5 cm and depend on the type of the active region.

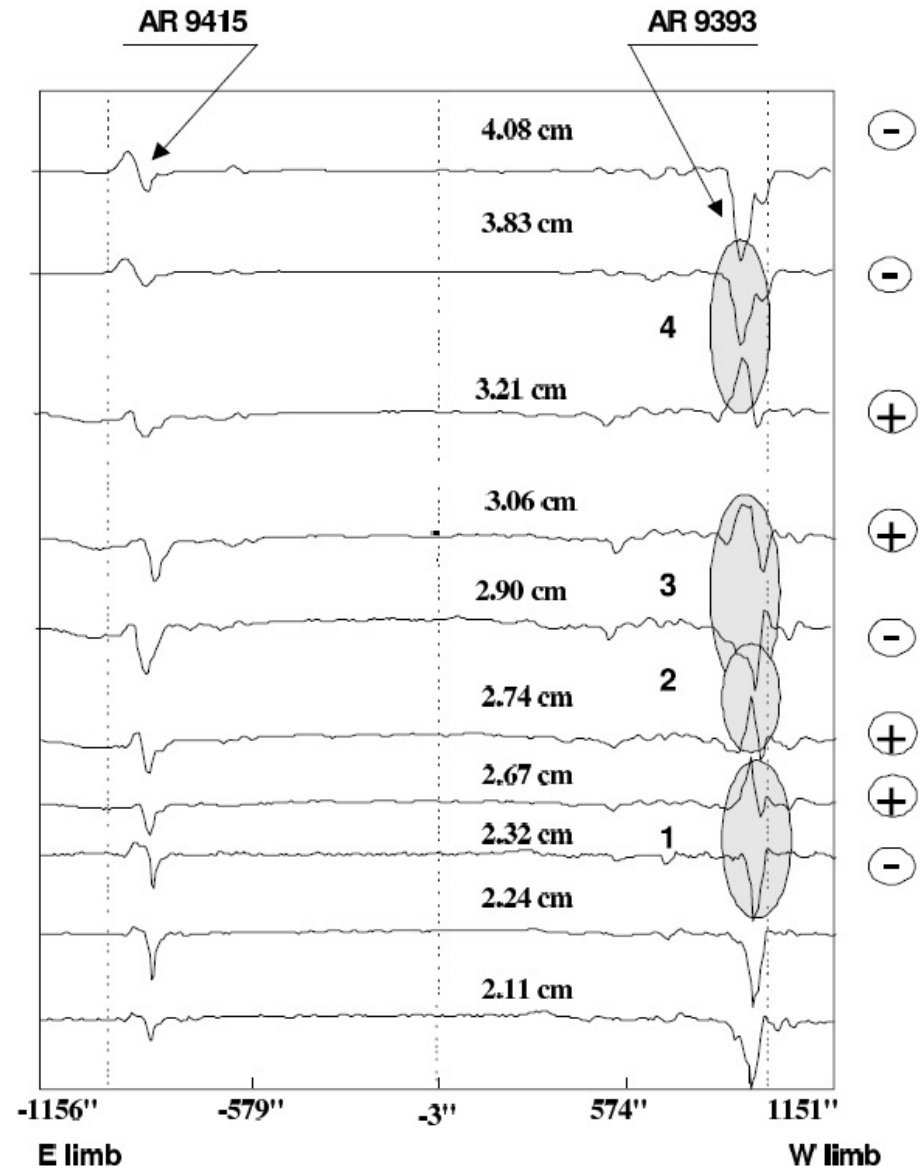
Features of the preflare plasma in the range 2.0 cm – 5.0 cm observed with RATAN-600

- I. Short-wave FPAR polarization emission brightening
- II. Polarization inversion at short centimeter waves
- III. Appearing of the low polarization band in frequency spectrum



Features of the preflare plasma in the range 2.0 cm – 5.0 cm observed with RATAN-600

- IV. Multiple inversions of polarization sign



Features of the preflare plasma in the range 2.0 cm – 5.0 cm observed with RATAN-600

- V. Darkening effect several hours before the flare
- VI. Polarization flux variations in broad frequency band before and after a big flare

- All these results are indicative of continuous processes of energy accumulation and preliminary heating of the magnetosphere of the active region over a wide range of heights.

- It is interesting that all the specific features of active regions that show up at centimeter-wave frequencies are almost always accompanied by decimeter- and meter-wave bursts.

Tanaka-Enome criteria

- *Tanaka H., Enome S., 1975*
 - 1) Flux (3cm) > 10 s.f.u.
 - 2) the flux ratio 3 cm/ 8cm (10cm) > 0.8
- variations: 3 cm/ 10cm > 1
- 3) 1-dim distribution of polarized emission at 3 cm E or P configuration

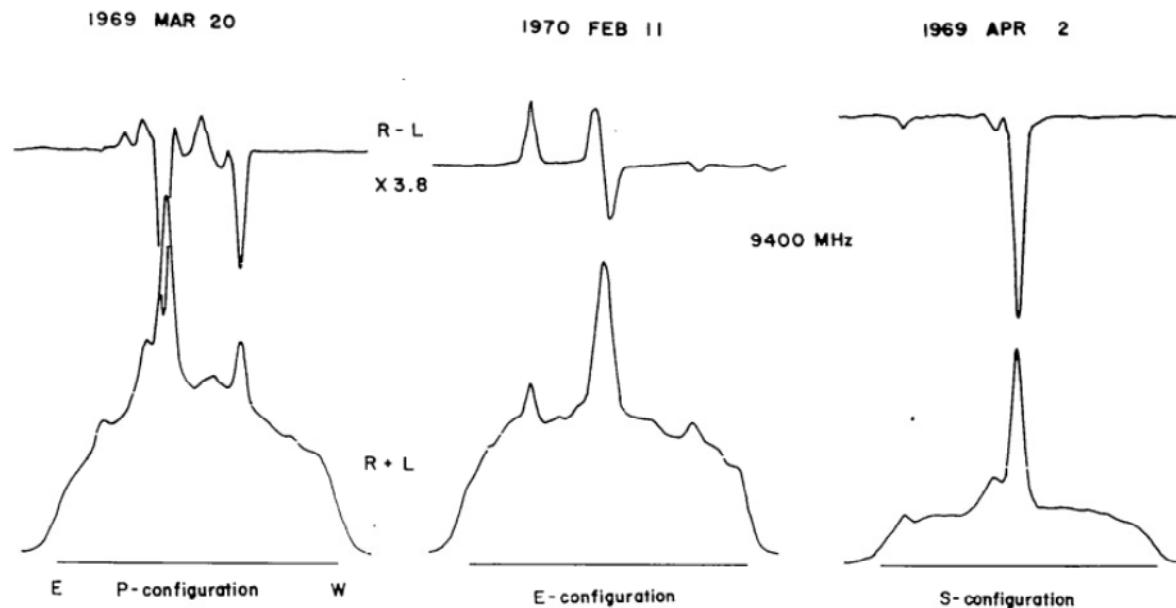


Fig. 2. Strip-scan curves of the Sun in intensity ($R+L$) and polarization ($R-L$) at a wavelength of 3 cm showing examples of P-, E- and S-configurations.

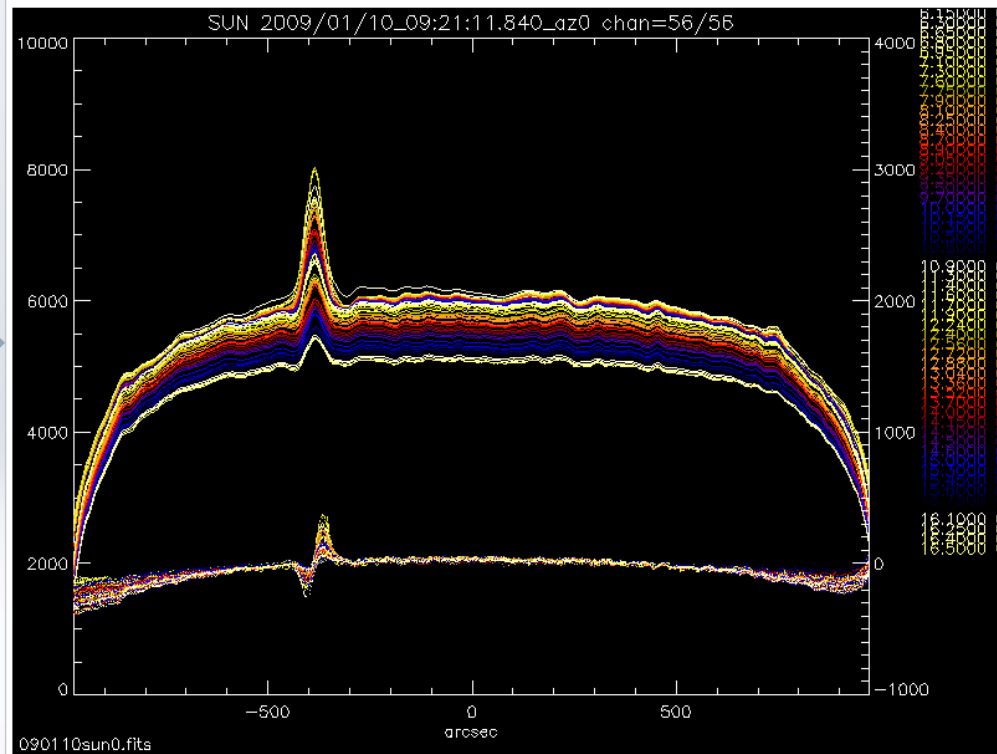
- **The intelligent knowledge-based system (IKBS) with a network access is used now for on-line treatment of solar observational data of the large radio telescope RATAN-600 at http://www.spbf.sao.ru/prognoz/index_eng.php**
- The system can be used for selection of observational data, estimations of observable parameters of solar sources, and evaluation of physical parameters of these sources by means of modeling.

RATAN-600 data search, display, and analysis

Object Year Month Day Azimuth Type Window size

Filter out bad channels Cut off Noise Gen. record Subtract zero level R&L->I&V Calibrate Center

Date is : 2009, 1, 10, Azimuth: 0



Overplot:
2D image Frequency Color Table Overplot color

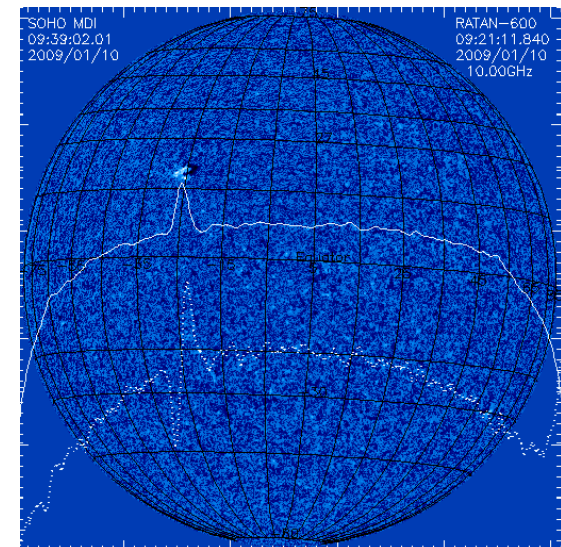
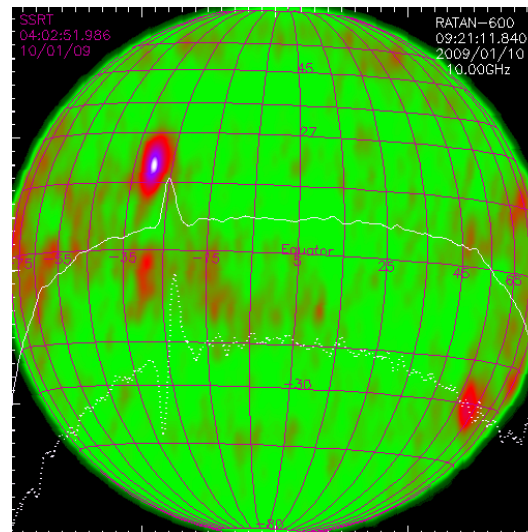
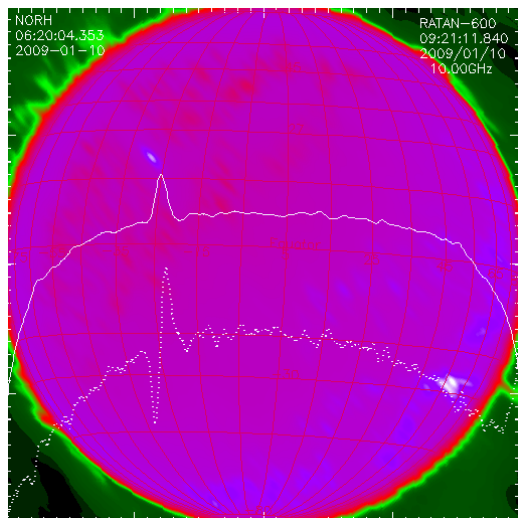
[HOME](#) DATA: [LATEST](#) [SEARCH](#) [ANALYSIS](#) [ARCHIVE](#)

Information

The following functions are available on the page:

- Search of RATAN-600 data by date and azimuth;
- Primary data processing, which includes: faulty channels deleting, cutting out of the calibrator record, conversion of the Stokes parameters R&L to I&V, calibration of scans based on the level of the quiet Sun. The resulting processed data are available for downloading in FITS and GIF formats through the links below the image.
- It is possible to choose various types of visualization, based on corresponding IDL functions (see the 'Type' drop-down list): 'I map', 'V map', 'I 3D', 'V 3D', 'I shaded surface', 'V shaded surface', '-V shaded surface', 'Raw data', 'I&V closeup', 'V vertical' etc),
- Subtraction of the quiet Sun level, which is an essential part of the RATAN-600 data processing, is performed in all modes, which include '-qsun' string in the name of the image type. The level of the Q.Sun can be viewed in the mode 'I-qsun template'.
- Automatic recognition of local sources is performed in the mode 'Find local sources'. Gauss-analysis of these sources is performed on the button 'Get all parameters of sources' (below the image).
- Comparison with other data (mostly 2D radio images) is performed on the 'Overplot' button.
- Local spectra of I&V antenna temperature are get on 'Plot Spectrum' button.

- 1.RATAN-600 solar observational data archive
- The circularly polarized solar emission (right and left polarization) are regularly registered in a broad range of microwaves **(1-18 GHz with 1% spectral resolution)**.
- Presented here an intelligent information system is intended to a data collection, storage, processing, analysis, modeling and a convenient using of the large data archive via the interactive web applications.
- The system carries out an automatic quality control and preprocessing of the data, a search of active regions and their identification. The system provides the web interface on ION (IDL on The Net) Script to analyze a data , to compare with data of other observatories (SOHO, SSRT, Nobeyama) and so on.

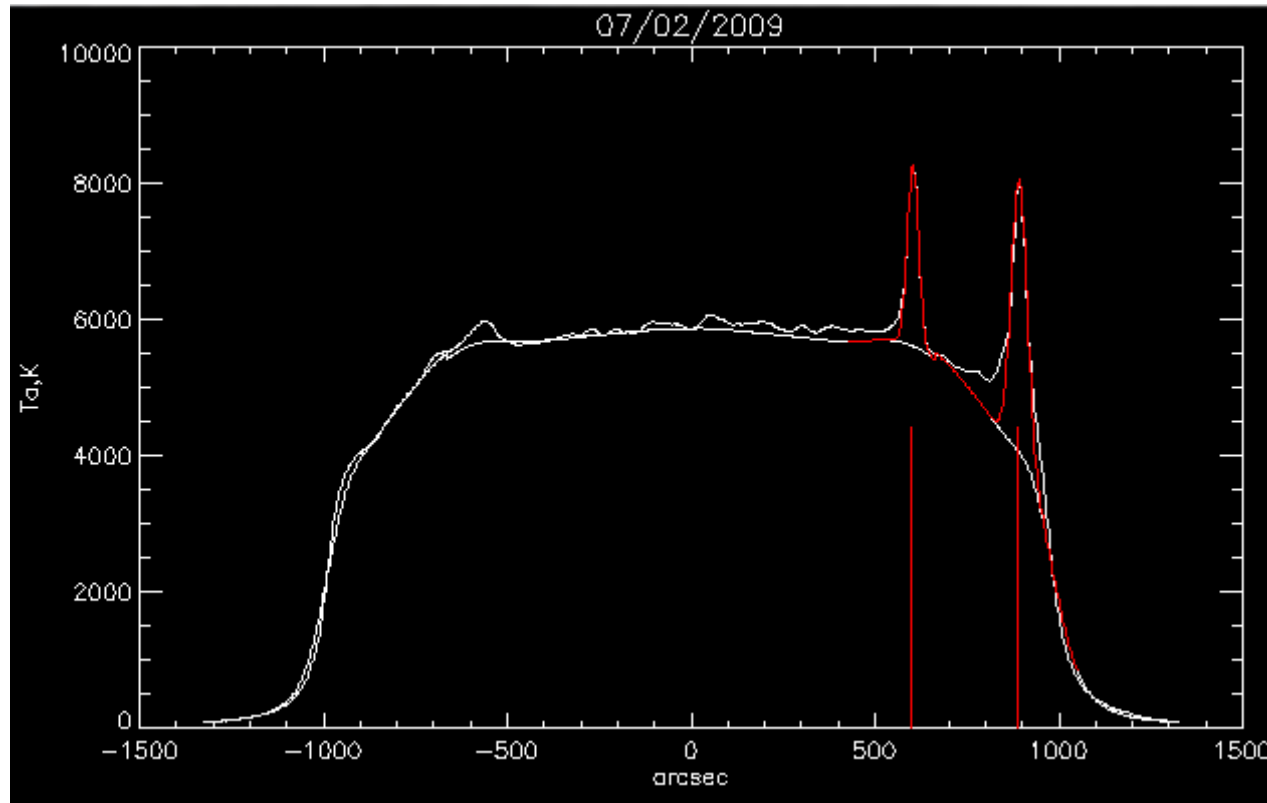


- 2. Data analysis
- The system provides the web interface to:
- **search of RATAN-600 data by date and azimuth,**
- **calibrate of scans based on the level of the quiet Sun,**
- **subtract the quiet Sun level,**
- **retrieve an intensity spectra of a selected point of the Sun.**

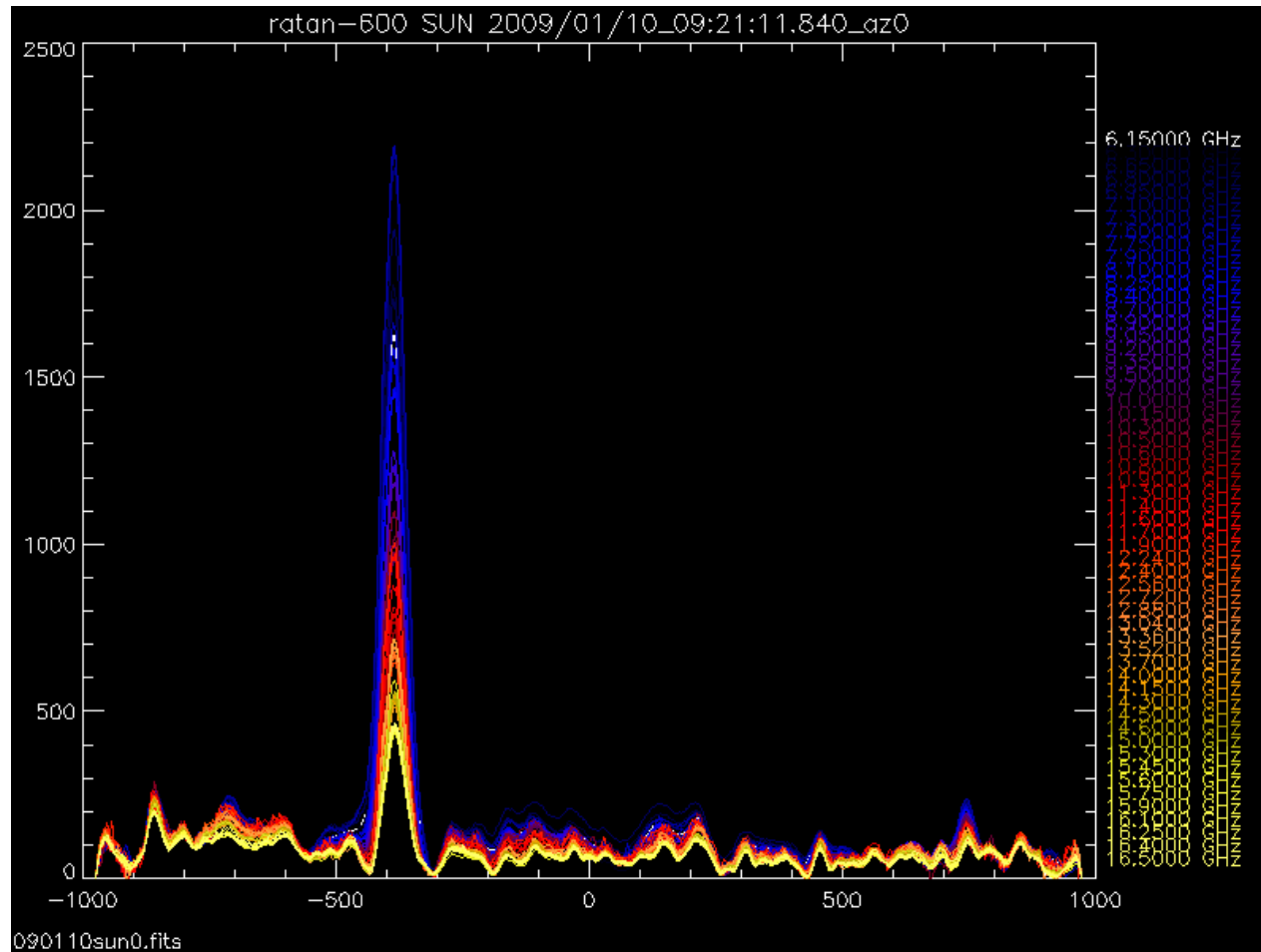
The results of processed data are available for downloading in FITS and GIF formats.

The results of an express Gauss-analysis are also available for the more prominent radio sources of AR as a table filled with a source size, flux density, brightness temperature and polarization degree through the frequency range.

The calibrated scan with the quiet Sun level and Gaussians approximations of bright sources.



RATAN-600 calibrated data (all frequencies) after subtraction of the quiet Sun level.



- A web-system for automatic analysis of the data and solar flares prediction on the base of Tanaka-Enome criterion has been created.
- In the study the spectral-polarization observations with RATAN-600 in wide frequency range were used.
- The idea was to modify the Tanaka-Enome's criterion for improving the prediction results for solar flares of different levels.

- A statistical analysis was fulfilled on the base of observations during 2011- 2013
 - From June, 1, 2011 to Jan, 27, 2013
- 4677 observations were analyzed
-
- The results of using the web-system are presented on the site <http://www.spbf.sao.ru>
- The automatic prediction is realizing during a few minutes after each observation.

- $A = \{F_{3\text{cm}} > 10 \text{ c.e.n. and the flux ratio } 3\text{cm}/10\text{cm} > 0.8\}$
- $B = \{\text{flare M or X in next 3 days}\}$
- $TP = (A \ \& \ B)$ - True Positive
- $TN = (!A \ \& \ !B)$ - True Negative
- $FP = (A \ \& \ !B)$ - False Positive
«false alarm»
- $FN = (!A \ \& \ B)$ - False Negative
“missed flares”

<i>TP</i>	<i>FN</i>
<i>FP</i>	<i>TN</i>

M and X flares

<i>80</i>	<i>398</i>
<i>145</i>	<i>4054</i>

Proton events

<i>11</i>	<i>52</i>
<i>214</i>	<i>4400</i>

- Accuracy: $ACC = \frac{TP + TN}{TP + FN + FP + TN}$

- True Skill Statistic: $TSS = POD - POFD = \frac{TP}{TP + FN} - \frac{FP}{FP + TN}$

	ACC	TSS
Proton events	94%	13.2%
Flares M and X	88%	12.8%

Examples of difficulties of automatic prediction

- The active regions are over plotted
- The region is on the limb
- The flare goes now

Tanaka-Enome proton flares prediction criterion Flux 3 cm >10 sfu, Flux 3cm/Flux 10 cm >1)

NOAA ARs for today: 1745 1746 1748 1753 1754 1755 1756

Time	az	NOAA AR	x pos	y pos	flux 3 cm	flux 3 cm corr	flux 10 cm	flux 10 cm corr	location	area	proton flare prognosis
07:01:16	+30	1745	914	-4.5	2.30	2.58	3.40	3.48	N13W66	120	negative
07:01:16	+30	1748	536	-1.3	4.00	4.04	3.10	3.11	N13W30	120	negative
07:01:16	+30	1755	-616	9.2	9.80	16.09	6.00	6.60	N10E62	120	positive
07:10:00	+28	1745	918	-4.3	2.70	3.00	9.80	10.01	N13W66	120	negative
07:10:00	+28	1748	537	-1.1	5.10	5.14	8.30	8.31	N13W30	120	negative
07:10:00	+28	1755	-627	9.0	13.70	22.06	16.30	17.87	N10E62	120	positive
07:18:42	+26	1745	915	-4.1	2.80	3.07	9.60	9.78	N13W66	120	negative
07:18:42	+26	1748	533	-1.0	4.70	4.72	8.20	8.21	N13W30	120	negative
07:18:42	+26	1755	-641	8.9	13.00	20.57	16.70	18.25	N10E62	120	positive
07:27:22	+24	1745	924	-3.8	2.60	2.82	10.20	10.37	N13W66	120	negative
07:27:22	+24	1748	535	-0.8	4.80	4.81	8.30	8.31	N13W30	120	negative
07:27:22	+24	1754_1755	-576	8.7	2.50	3.89	17.10	18.63	S16E38	20	negative
07:27:22	+24	1756	-698	0.7	10.10	10.13	17.10	17.12	S20E54	100	negative
07:36:01	+22	1745	923	-3.6	2.60	2.80	9.90	10.05	N13W66	120	negative
07:36:01	+22	1746	528	-12.6	4.80	12.00	8.40	10.06	S28W64	130	positive
07:36:01	+22	1754	-570	0.2	2.70	2.70	17.50	17.50	S16E38	20	negative
07:36:01	+22	1756	-704	0.5	10.00	10.02	17.50	17.50	S20E54	100	negative
07:44:38	+20	1745	924	-3.4	2.40	2.56	9.90	10.03	N13W66	120	negative
07:44:38	+20	1746	519	-12.5	4.30	10.54	8.50	10.14	S28W64	130	positive
07:44:38	+20	1753_1754	-565	5.9	2.40	2.94	17.50	18.21	N04E47	60	negative
07:44:38	+20	1756	-699	0.3	10.10	10.11	17.30	17.30	S20E54	100	negative
07:53:15	+18	1745_1755	928	-3.2	2.50	2.65	10.30	10.41	N13W66	120	negative
07:53:15	+18	1746	528	-12.4	4.80	11.59	8.80	10.46	S28W64	130	positive
07:53:15	+18	1753_1754	-564	5.8	2.20	2.68	17.90	18.59	N04E47	60	negative
07:53:15	+18	1755_1756	-694	8.2	10.70	15.88	17.70	19.09	N10E62	120	negative

Summary

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