# “Struve arc” as indicator of the manifestation of solar and geomagnetic activity

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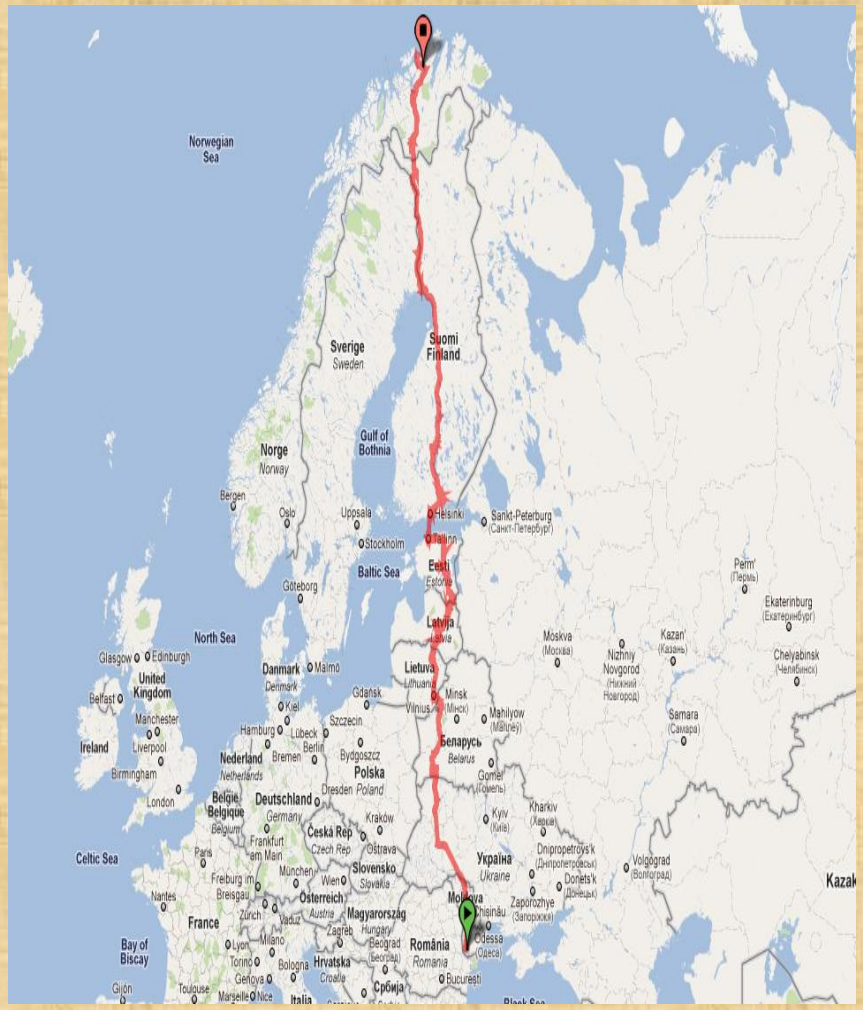
**Ventspils International Radio Astronomy Center**

# Struve Geodetic Arc




- The **Struve Geodetic Arc** is a chain of survey triangulations stretching from Hammerfest in Norway to the Black Sea, through **10 countries** and over 2,820 km, which yielded the first accurate measurement of a meridian arc

# "Struve's Geodetic Arc"

- This project was named "Struve's Cosmic Arc" in honor of the outstanding international project of the 19- th century **"Struve Geodetic Arc",** which united scientific, technical and intellectual resources of different countries to study the shape of the Earth. It included **265 triangulation points** with length of more than 2820 kilometers (from Hammerfest city, Norway through Sweden, Finland, Russia, Estonia, Latvia, Lithuania, Belarus, Moldova and Ukraine to the Black Sea coast). Research was carried out to determine parameters of the Earth, its shape and size. Measurements under the Struve Geodetic Arc Project were carried out for 40 years (from 1816 - 1855) under guidance Director of Pulkovo Observatory **Friedrich Georg Wilhelm Struve**.

# Postal block " Struve Arc" in Latvia.

# V.Ya.Struve (1793-1864)

**Director of the Pulkovo Observatory (1839-1862).**

**In 2005**, the chain was inscribed on the World Heritage List, because of its importance in geodesy and its testimony to international scientific cooperation


# Memorial Stations «Struve Arc»


# Struve Arcs tools

# The goal of the project "Space Arc Struve".

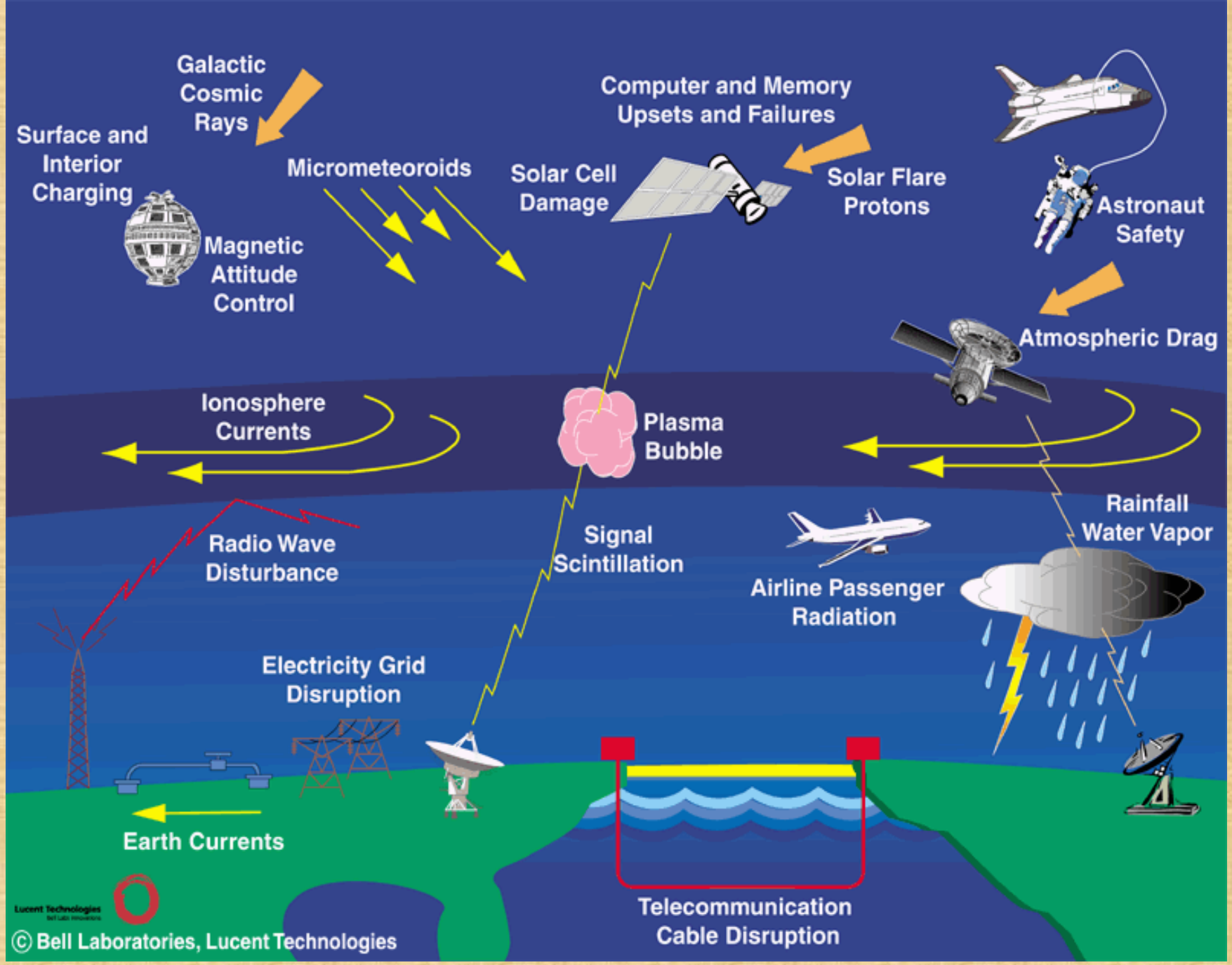
- **The aim of this project is to study the nature of the influence of space weather effects depending on the latitude and regional features of the geomagnetic field (regular field and magnetic anomalies) in the "Latvian" and "Ukrainian" parts of the Struve Arc.**

# Initiators of the project

- - **Latvia** (Ventspils International Radio Astronomy Centre (**VIRAC**) of Ventspils University of Applied Sciences (**VUAS**)
- **Ukraine** (Institute of Radio Astronomy of the National Academy of Sciences of Ukraine (**IRA NASU**) – Odessa observatory “URAN-4”
- Institute of Geophysics of the National Academy of Sciences of Ukraine (**IGP NASU**), Kiev
- Institute of Physics and Mechanics of the National Academy of Sciences of Ukraine (**IPM NASU**) – observatory “URAN-3”.

# Space weather on the Earth – what is it?

- **Interaction of the Sun, the Moon and Earth form conditions of "space weather" on the Earth.**
- **Structure of system: Solar activity- Solar wind- Moon tides- Solar tides- Geomagnetic activity- Ionosphere- Regular and Anomaly geomagnetic fields.**


Galactic Cosmic Rays
Surface and Interior Charging
Micrometeoroids
Computer and Memory Upsets and Failures
Solar Cell Damage
Solar Flare Protons
Astronaut Safety
Magnetic Attitude Control
Atmospheric Drag
Ionosphere Currents
Plasma Bubble
Rainfall Water Vapor
Radio Wave Disturbance
Signal Scintillation
Airline Passenger Radiation
Electricity Grid Disruption
Earth Currents
Telecommunication Cable Disruption
Lucent Technologies
© Bell Laboratories, Lucent Technologies

# Main equipments

**VIRAC** - radio telescopes 32-m and 16-m antenna in centimeters and decimeter range and LOFAR in 10 - 220 MHz range.

**RI NANU** – radio telescopes “URAN-4” (Odessa)
“URAN-3” (Lviv)

**IGP NANU** – magnetic observatory ( Odessa, Kiev, Lviv)

# Observatory Ventspils International Radio Astronomical Center (VIRAC)

# 32-m and 16-m radio telescopes of the Ventspils International Radio Astronomy Center, Latvia

+ uncooled
1.6 GHz receiver

32-m

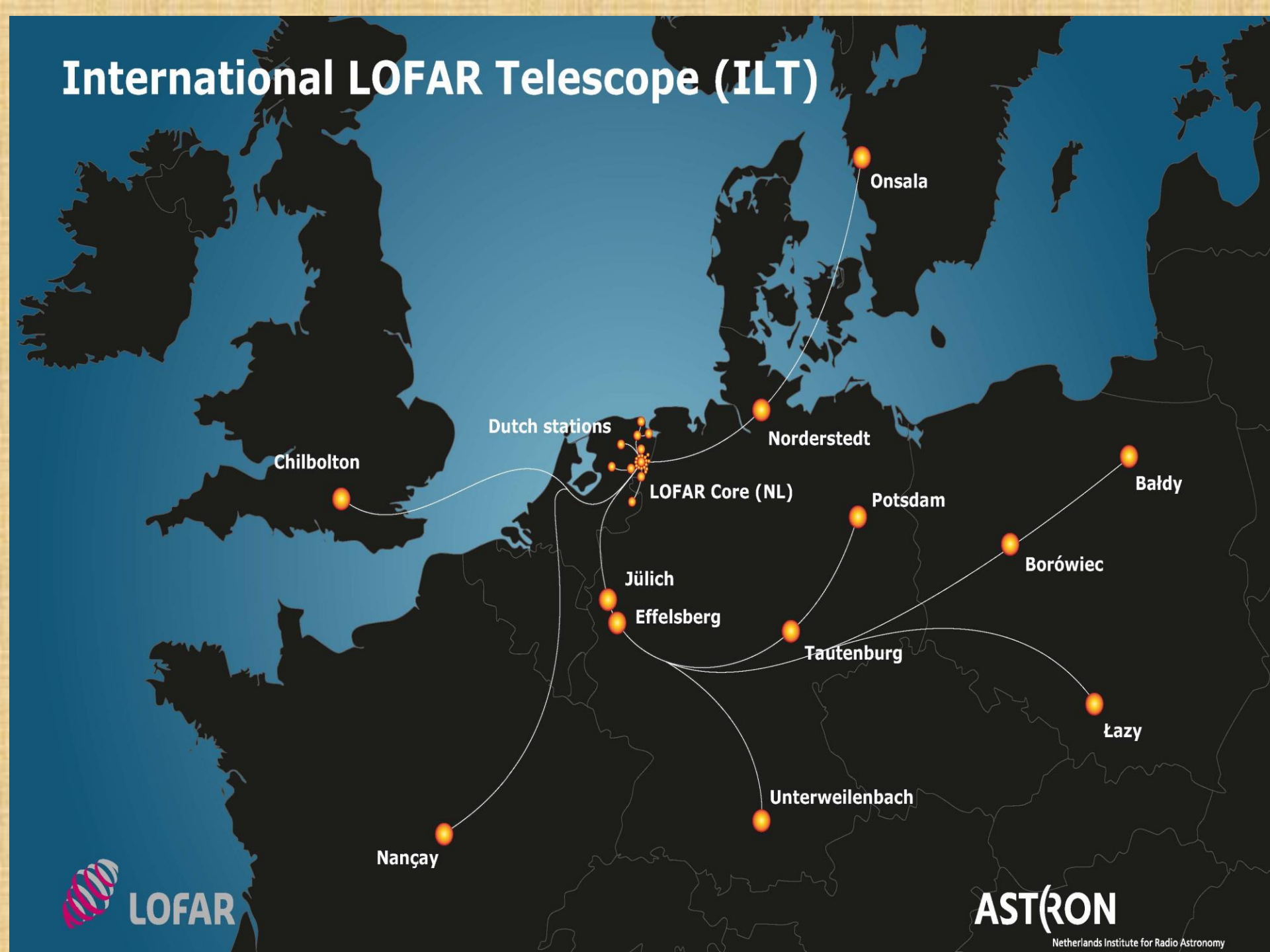
16-m

Operating frequencies 5, 6.1, 6.7, 8.4 GHz + circular polarizations (left LCP, right RCP)

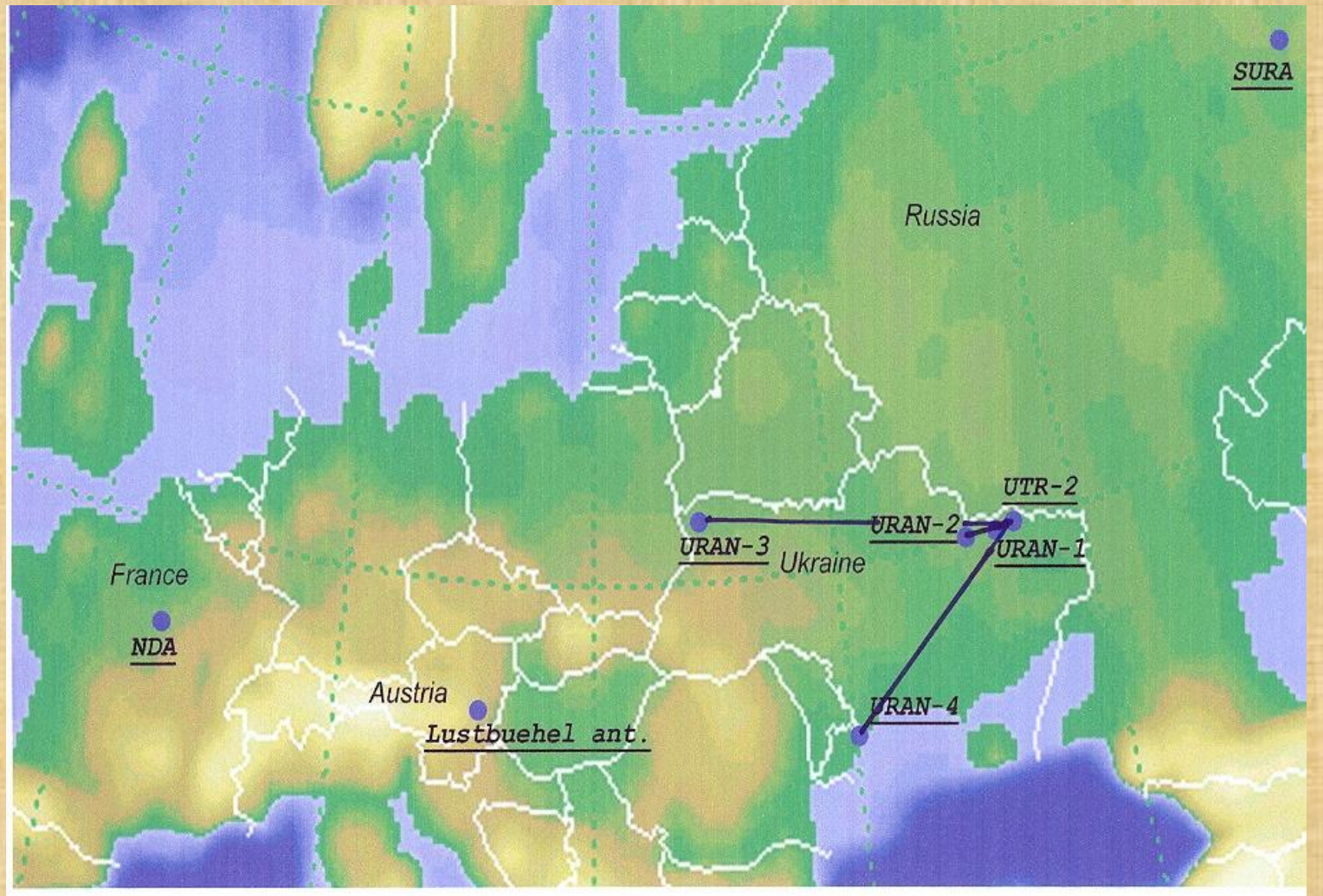
# LOFAR VIRAC ( decameter range)

# Antenna array LOFAR VIRAC (meter range)

# Radio telescope PT-32 VIRAC


International LOFAR Telescope (ILT)
Onsala
Dutch stations
Norderstedt
Chilbolton
LOFAR Core (NL)
Potsdam
Bałdy
Borówiec
Jülich
Effelsberg
Tautenburg
Łazy
Unterweilenbach
Nançay
LOFAR
ASTRON
Netherlands Institute for Radio Astronomy

# VLBI – “URAN”




Место УРАН среди других инструментов декаметрового диапазона

# Radio telescope “URAN-3”

**From the beginning of observations in 1987 year at a radio telescope "URAN-4" the fluxes monitoring of high-power galactic and extragalactic radio sources is carried out.**

**The radio telescope URAN-4 is the rectangular antenna lattice consisting of 128 broadband vibrators located in the direction the East – the West (220x22m). The size of diagram the W – E direction is equal 2,8º. Fluctuation sensitivity is 150 Jy.**

# Program of monitoring

**3C144**

- $\alpha = 05^h\ 31^m\ 30^s$ $\delta = 21^\circ\ 39^m$

**3C274**

- $\alpha = 12^h\ 28^m\ 18^s$ $\delta = 12^\circ\ 40^m$

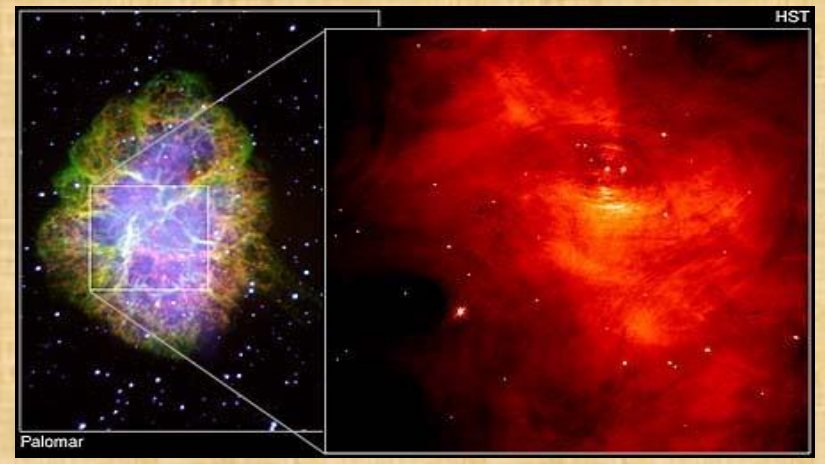
**3C405**

- $\alpha = 19^h\ 57^m\ 47^s$ $\delta = 40^\circ\ 36^m$

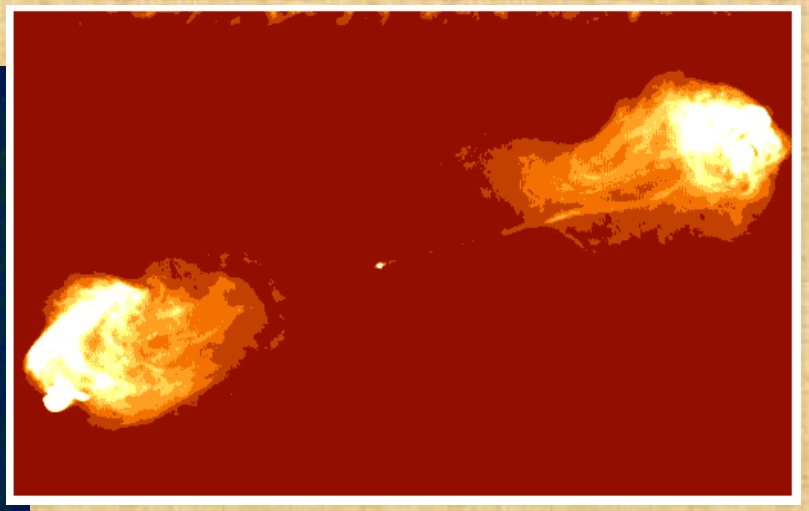
**3C461**

- $\alpha = 23^h\ 21^m\ 07^s$ $\delta = 58^\circ\ 34^m$

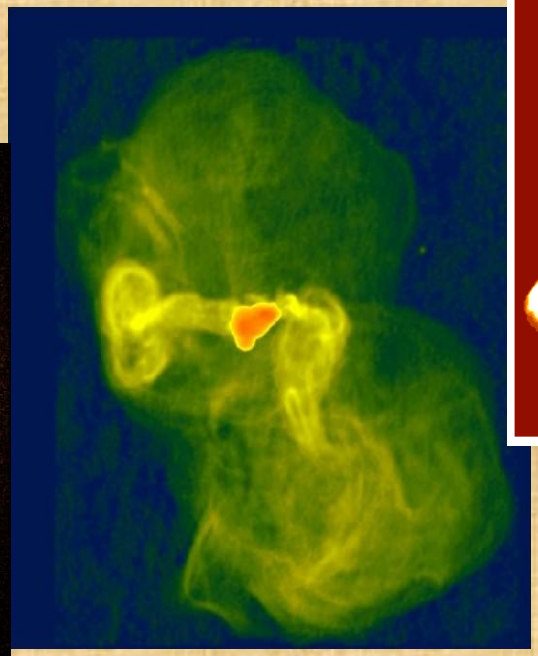
- **3C144 (Crab Nebula – SNR)**



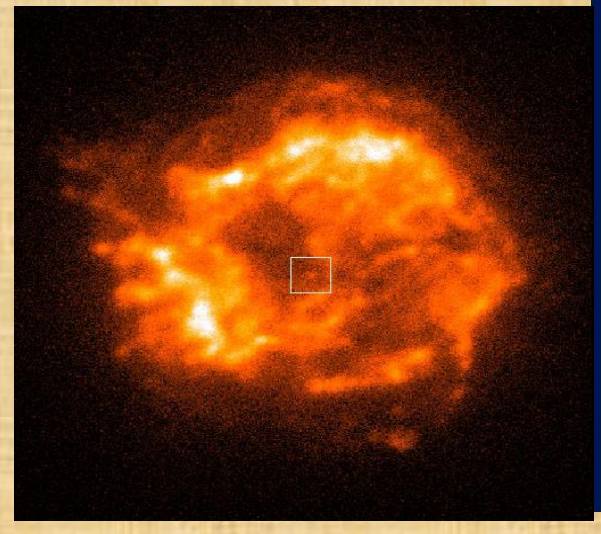

- **3C405-CygA-Radiogalaxy**



- **3C274 – VirgoA- Radiogalaxy**



- **3C461 – CasA - SNR**



# Observations of sources for 24h

**3C144**

-120m до + 120m , ΔT = 40m , 7 scans.

**3C274**

- 120m до + 120m , ΔT = 40m , 7 scans.

**3C405**

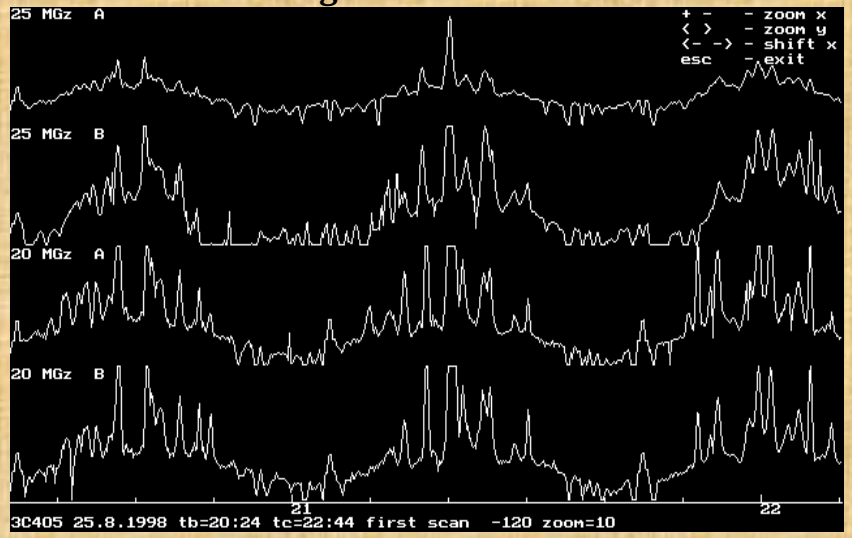
- 120m до + 80 m , ΔT = 40m , 6 scans.

**3C461**

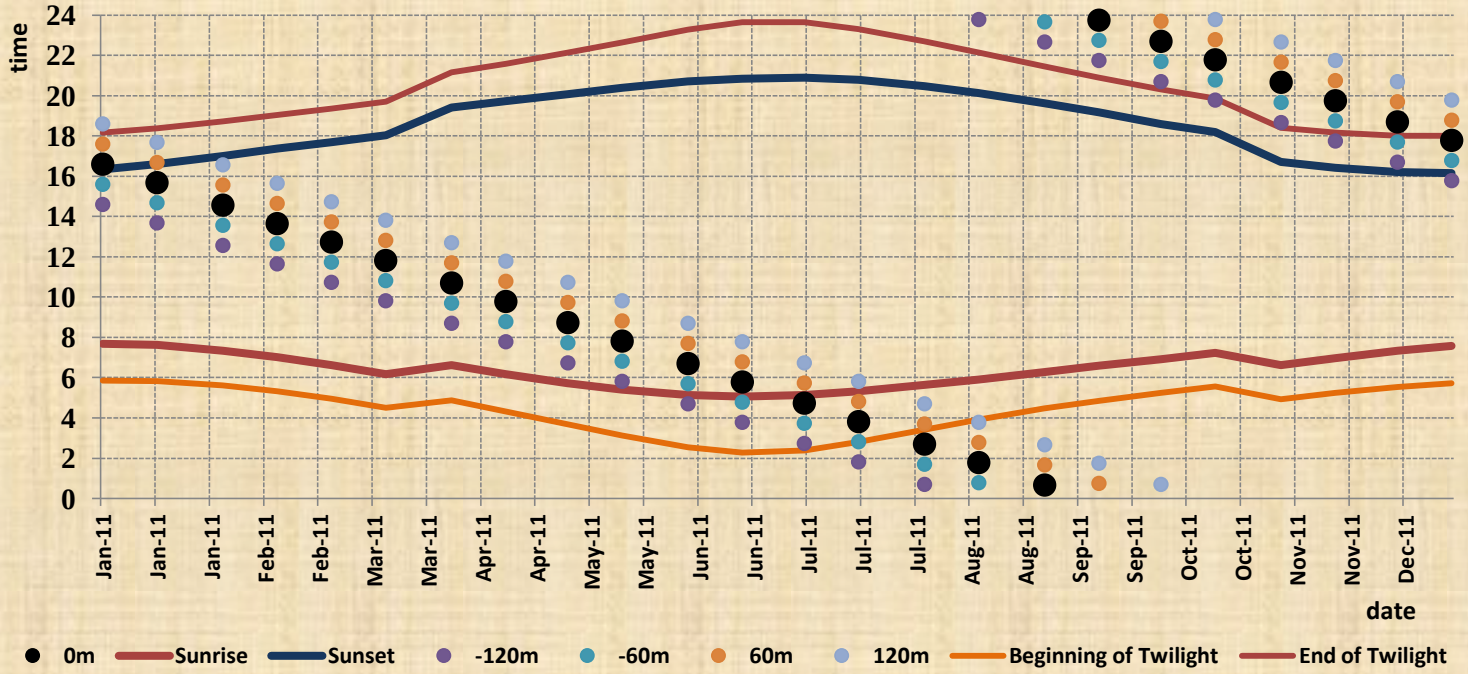
- 60 m до + 120 m , ΔT = 60m , 4 scans

total - 13 hours 20 minutes

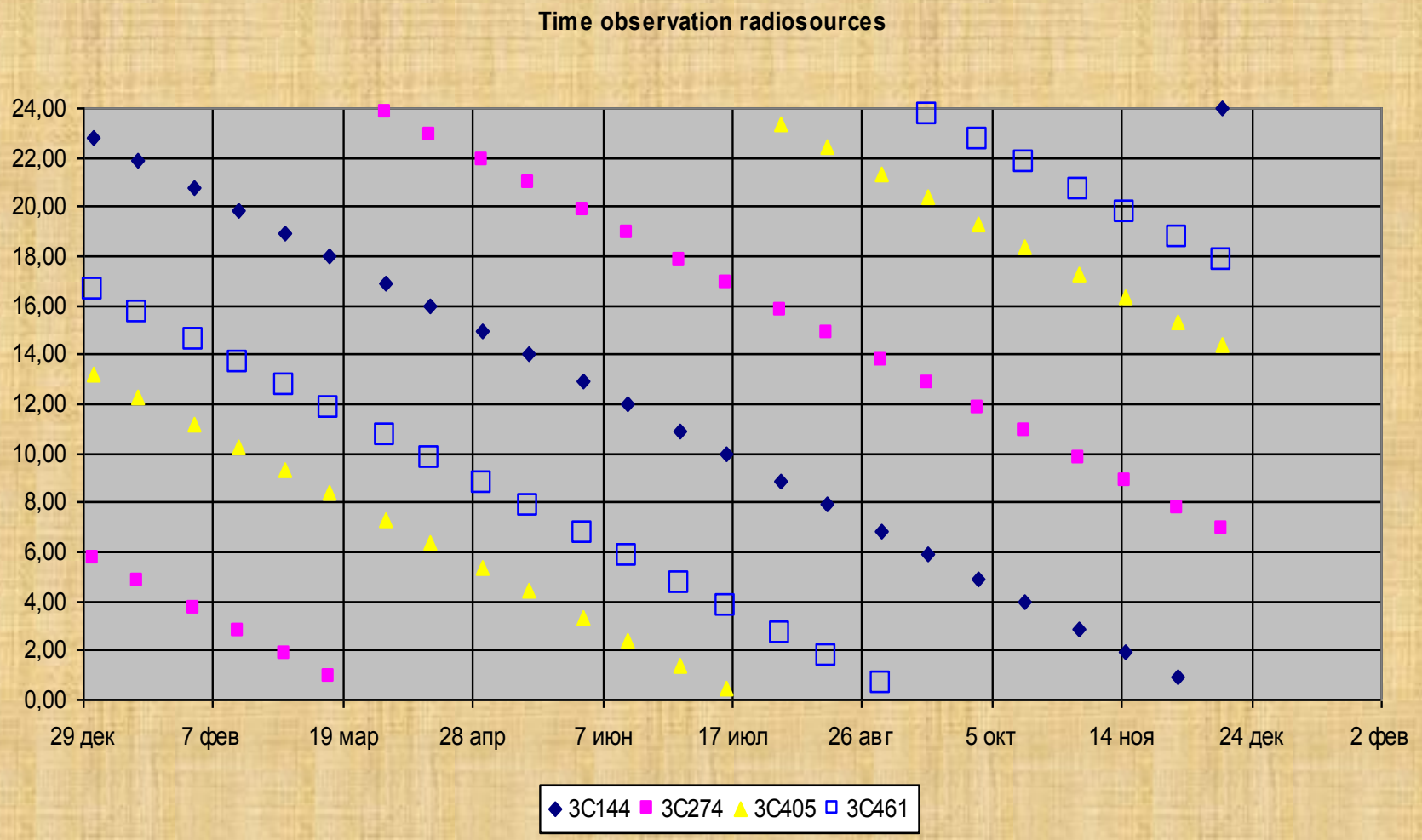
## Exemplar of record of a source 3C405 received in the automatic registration mode




## The observation time of a radiation source 3C 461



# Time observation radio sources



# Recorded effects.

- **Determination of regular seasonal-daily effects based on changes in radio source fluxes.**
- **Flickering of radio source fluxes as an indicator of wave processes in the ionosphere.**
- **Regional effects of radiation and magnetic storms according to observations of radio sources and variations of the geomagnetic field.**
- **Regular passage of tidal waves in the ionosphere according to flickering radio sources.**
- **Analysis of the features of the regional "response" of active solar and geomagnetic phenomena near magnetic anomalies in Odessa, Lviv and Ventspils.**
- **Features of the manifestations of the 25th cycle of solar activity in all observed phenomena.**

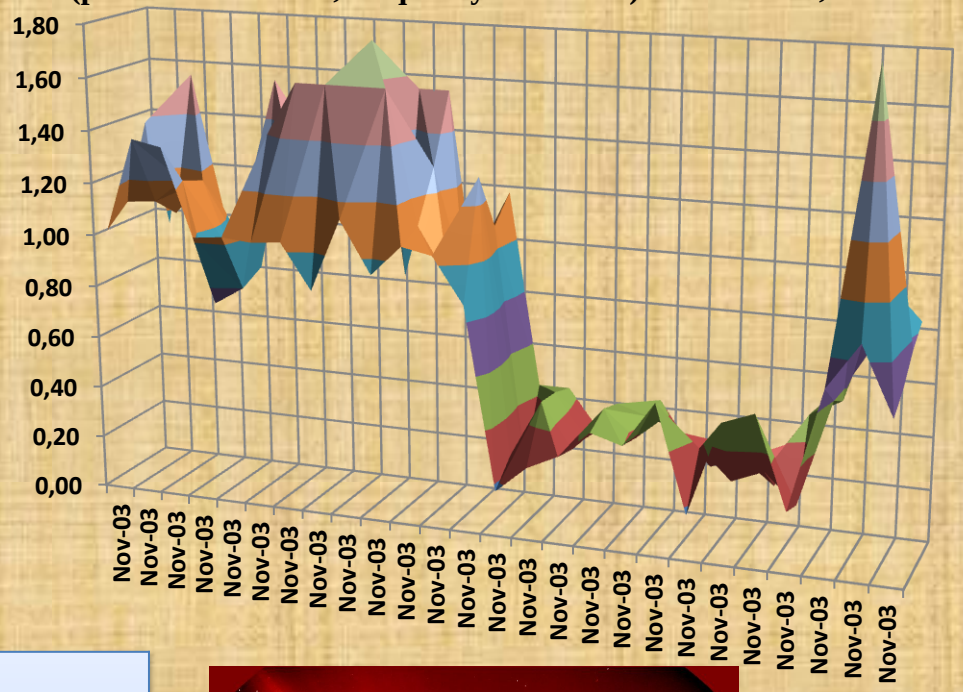
# The results of ours investigations.

- Effects of extreme states of solar and geomagnetic activity.
- Calculations of models of multiple correlation dependence of cosmic radio source fluxes on the main indices of solar and geomagnetic activity.
- Changes in the fluxes of space radio sources in the solar cycle.
- Detection of the effects of the passage of the lunar tidal wave according to the data of flickering space radio sources.
- Results of manifestations of geomagnetic activity in the zone of Odessa magnetic anomaly.

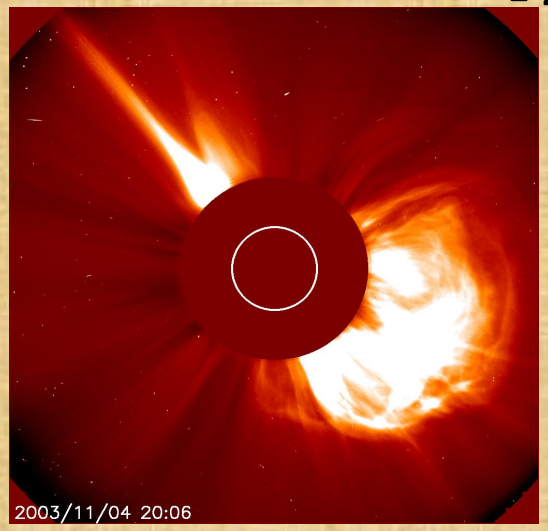
# Multiple Correlative models for a flux radio source 3C461 (the period - November, 2003)

Changes of a flux of a radiation source are shown by small decrease of a stream on November 3-5 and the most noticeable decrease of a stream from November 17 to November 27. During the period from November 2 to November 4 in the Sun there were 4 flares. The most potent flash (X>17.5) happened on November 4 that entailed recession in radiation source stream level. Recession of a stream of a radiation source was not too larger as the flash happened on the edge of a solar disk and its radiation poorly affected Earth. The next period of a superactivity began since November 17. It was followed by sharp recession of level of a flux of a radiation source which continued till November 27. For three days in this fissile area eight flaeres of point of M from which two were larger were made. The flare of point 2N during which there were two flashes of x-ray point of M3.2 and M3.9 was on November 18 the most interesting event of this period. Potent emission of coronal substance of this flare event caused during very larger and intensive magnetic storm on November 20-21.

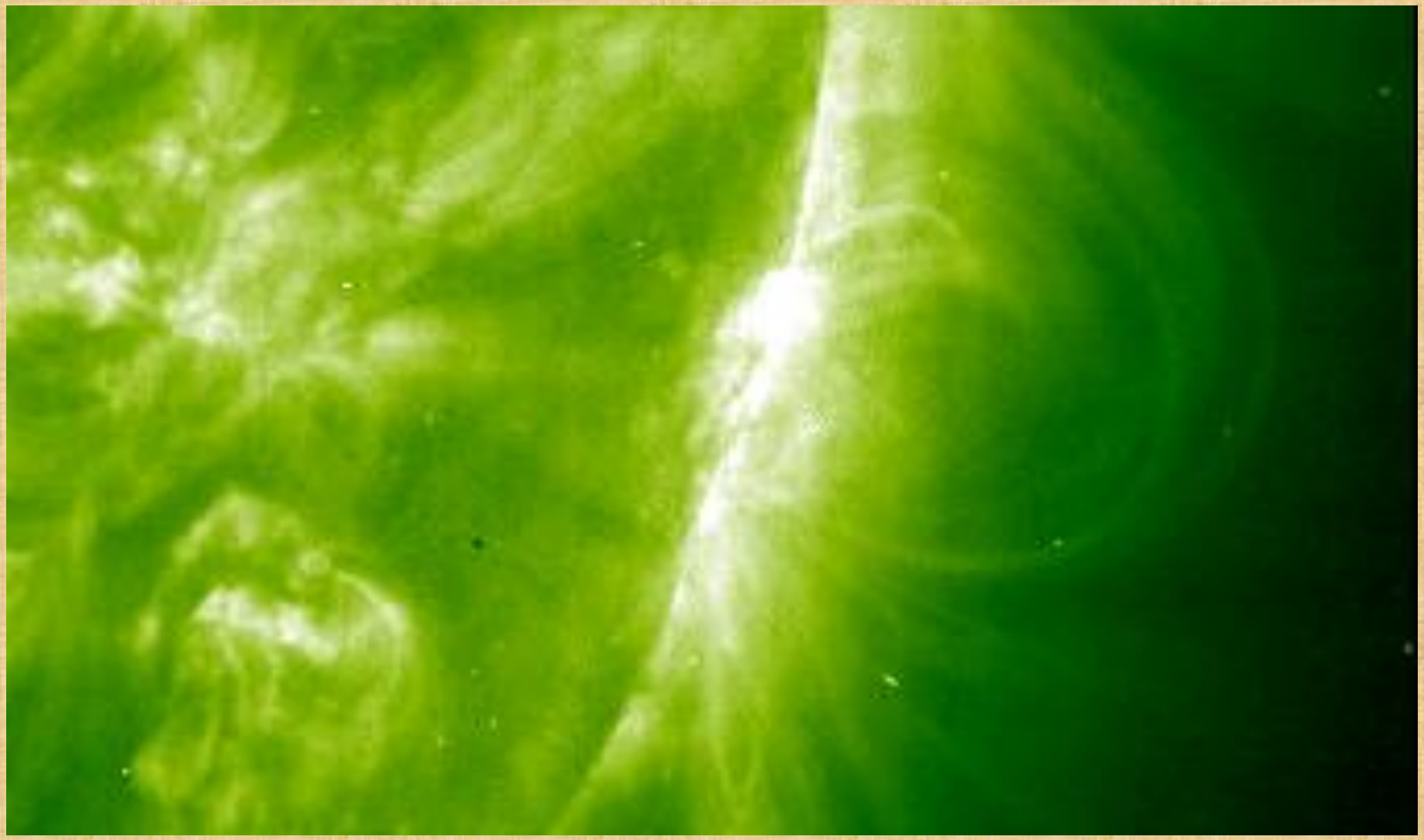
**3C461 radiation source flux variations on different hour corners (polarization – And, frequency – 25 MHz) in November, 2003**




| Date | Beginning UT | Duration min | Coordinates ϕ λ | Point | $I_{RB}$ | p.f.u. | $I_{ms}$ |
|---|---|---|---|---|---|---|---|
| 02.11.03 | 1703 | 171 | S14W56 | X8.3/2B | R3 | 1540 S3 | S 04.11 G2 |
| 03.11.03 | 0106 | 91 | N10W83 | X2.7/2B | R3 | | |
| 03.11.03 | 0943 | >36 | N08W77 | X3.9/2F | R3 | | |
| 04.11.03 | 1929 | 80 | S19W83 | X>17.5 ($11^m$) | R5 | 353 S2 | |
| 05.11.03 | 1046 | >12 | S16W90 | M5.3/SF | R2 | | |
| 18.11.03 | 0716 | 159 | N00E18 | 2N/M3.2/M3.9 | R1 | | VL 20-21.11 G5 |
| 20.11.03 | 0735 | 61 | N01W08 | M9.6/2B | R2 | 10 S1 | 22.11 G1 |
| 20.11.03 | 2342 | 16 | N00W17 | M5.8/2N | R2 | | |




**The flash which happened in the Sun on November 04, 2003**

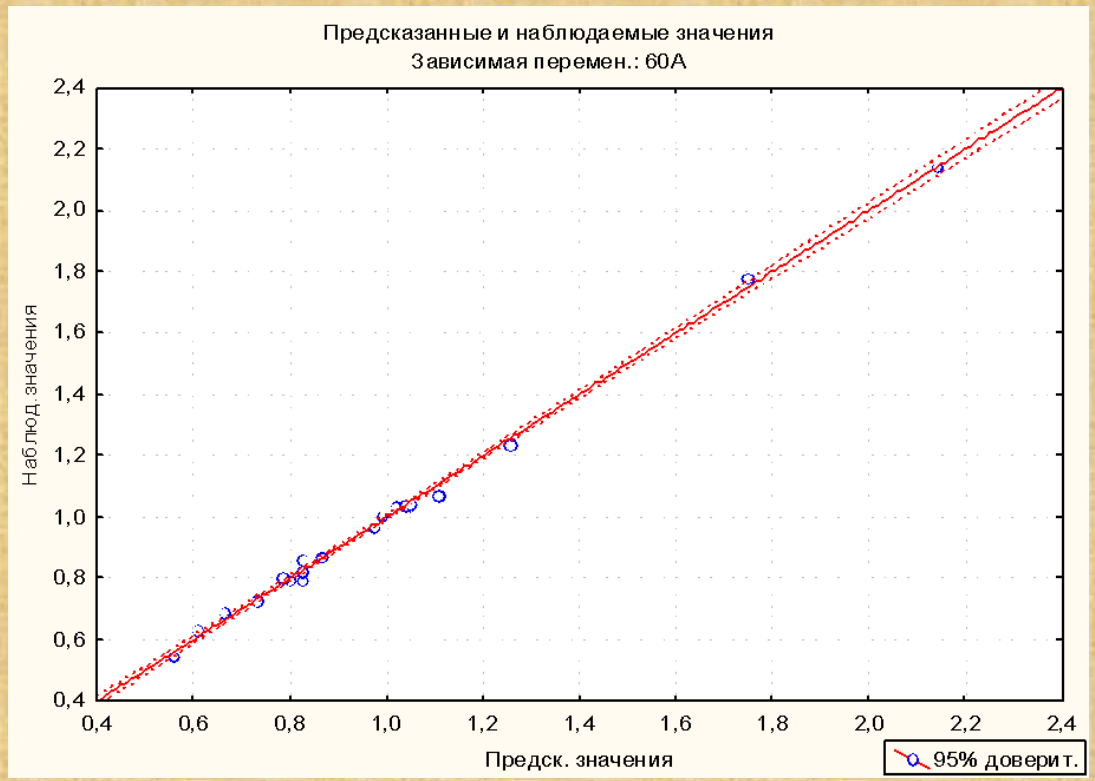


**Multiple correlation coefficient in the range 0,87 - 0,97. The largest values of private correlations in August 2005:**

- **indices reflecting solar activity:** N- S (Sp)
- **particle flows:** υ , ρ , P > 10 МэВ
- **indices characterizing the state of the magnetic field perturbation according to the data of the magnetic station "Odessa":** H, Z, D , Kp

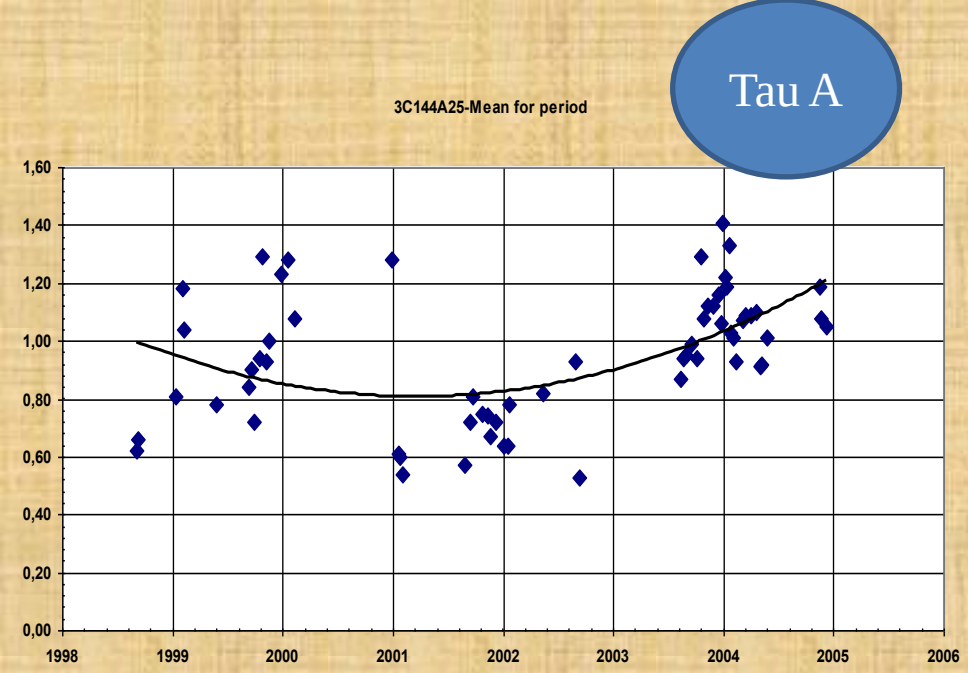
| Hour angle | -60m | 0m | 60m | 120m |
|---|---|---|---|---|
| Multiple R, max / Indexes | 0,97 | 0,87 | 0,89 | 0,94 |
| F10.7 | -0,3 | -0,36 | 0,61 | 0,64 |
| W | 0,17 | 0,35 | 0,47 | 0,7 |
| Sp | 0,31 | 0,38 | 0,93 | 0,62 |
| N-Sp | -0,61 | -0,79 | -0,99 | -0,81 |
| S-Sp | 0,57 | 0,81 | 0,99 | 0,77 |
| K | -0,54 | -0,8 | -0,94 | -0,75 |
| H | 0,81 | 0,86 | 0,99 | 0,81 |
| Z | -0,82 | -0,82 | -0,99 | -0,79 |
| D | -0,48 | -0,46 | -0,95 | -0,42 |
| P > 1 | -0,27 | -0,25 | 0,9 | 0,23 |
| P > 10 MeV | 0,7 | -0,7 | -0,97 | -0,73 |
| P > 100MeV | 0,5 | -0,45 | 0,91 | -0,36 |
| E >0,6 MeV | 0,66 | 0,3 | 0,83 | 0,42 |
| E >2 MeV | -0,28 | 0,33 | 0,88 | 0,63 |
| υ | 0,78 | 0,86 | 0,99 | 0,81 |
| ρ | 0,73 | 0,83 | 0,98 | 0,77 |

Summary table of results of calculation of multiple regression for radio source 3C 461 A25 MHz (November 2003).

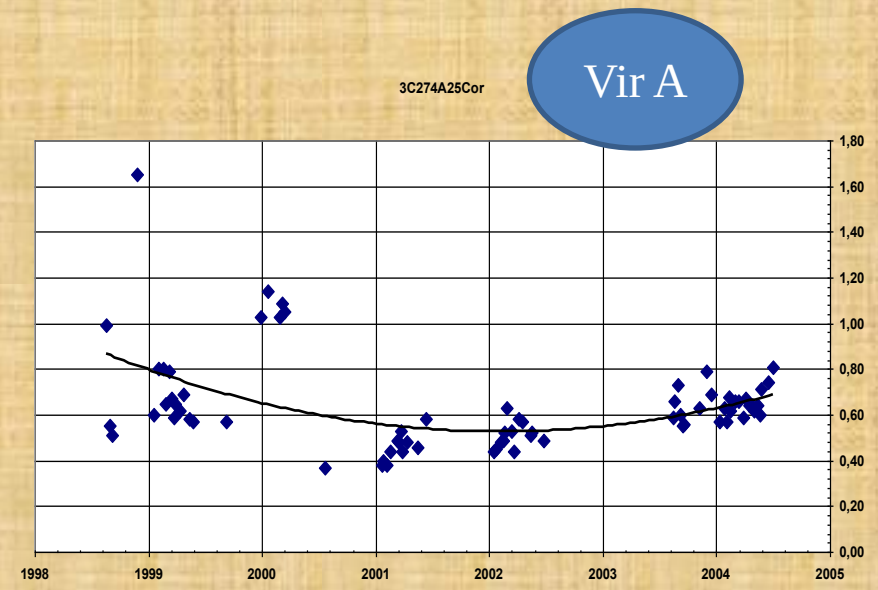



Graph of predicted and observed values for the source 3C 461 (August 2005)

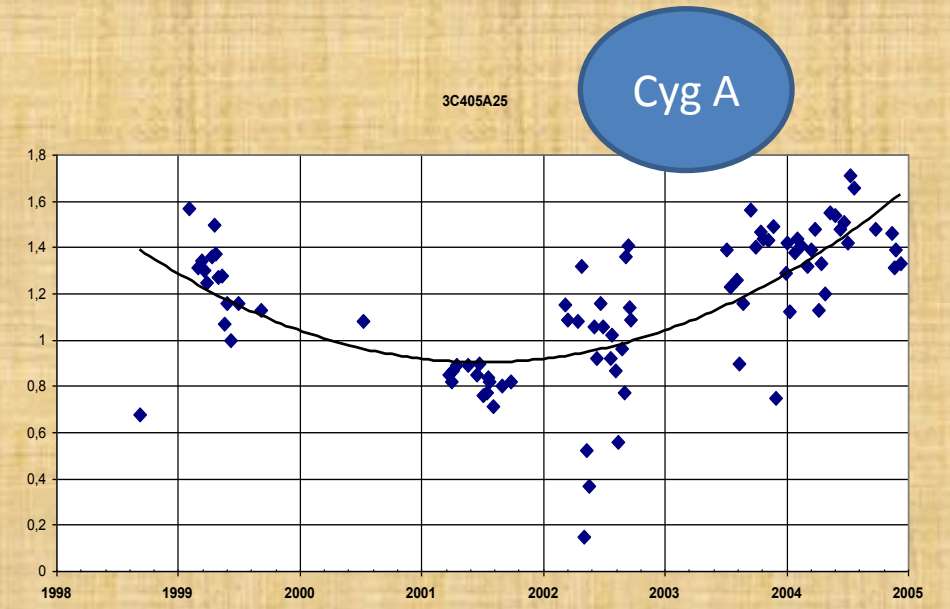
Tau A



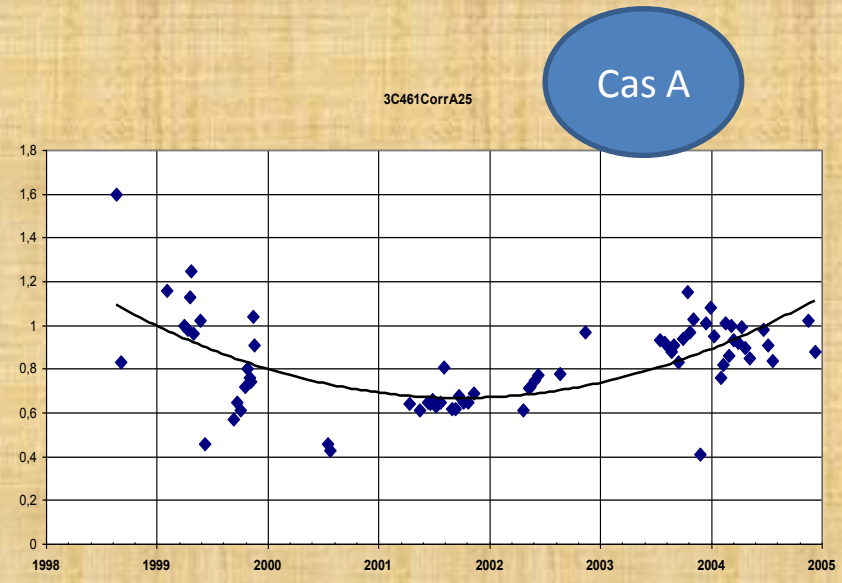

Vir A




Cyg A




Cas A



# Moon tidal phenomena in Ionosphere

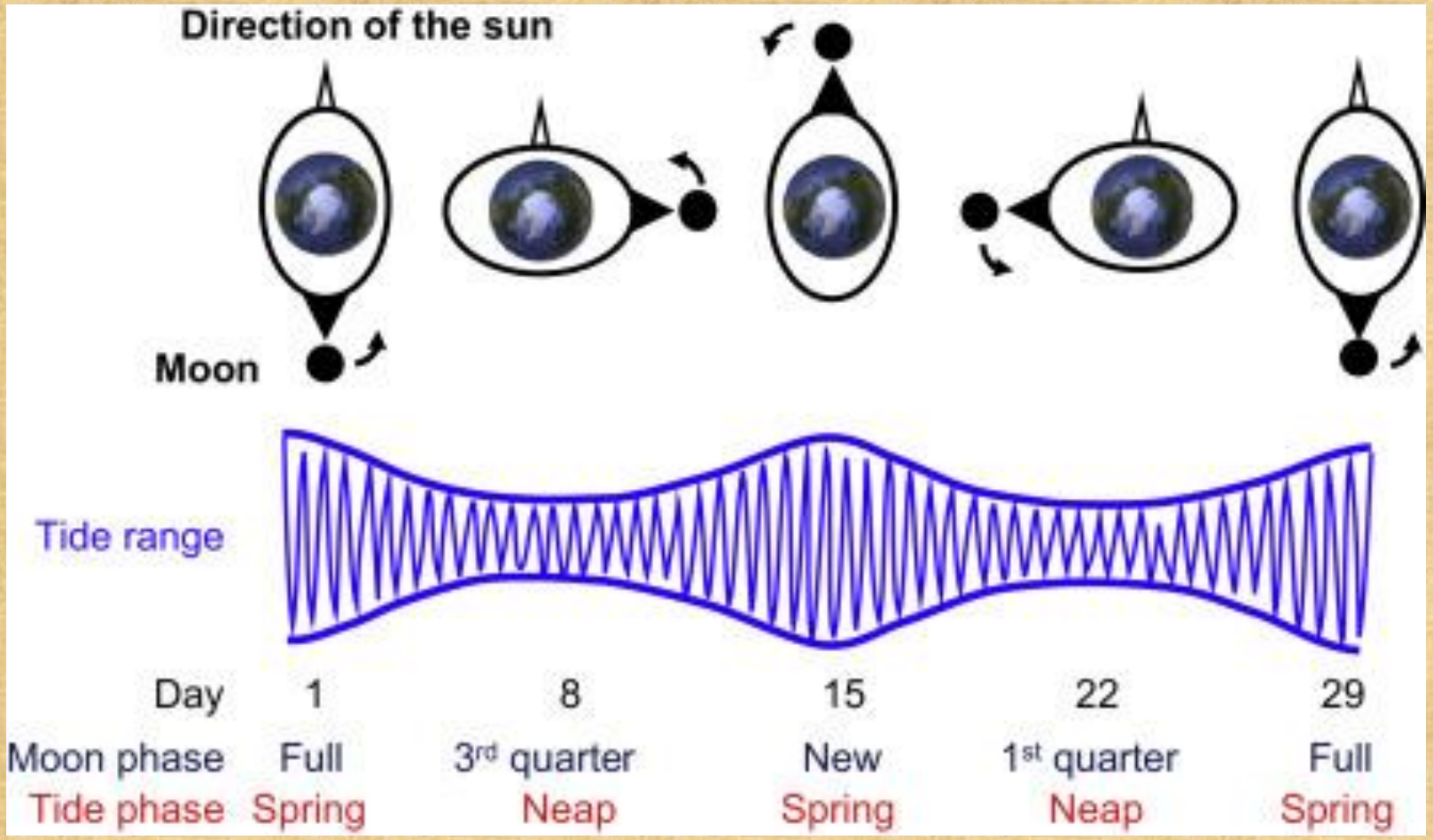
**Data monitoring flux densities of powerful radio-sourses on the Radio-telescope "URAN-4" for research of effects "plasma lensing" of lunar tides in Ionosphere.**

**Use of a radiotelescope "URAN- 4" allows to realize a radioastronomical method of supervision having tidal phenomena in the ionosphere of the Earth by a method registration focusing and defocusing radiosourses in decameter waves.**

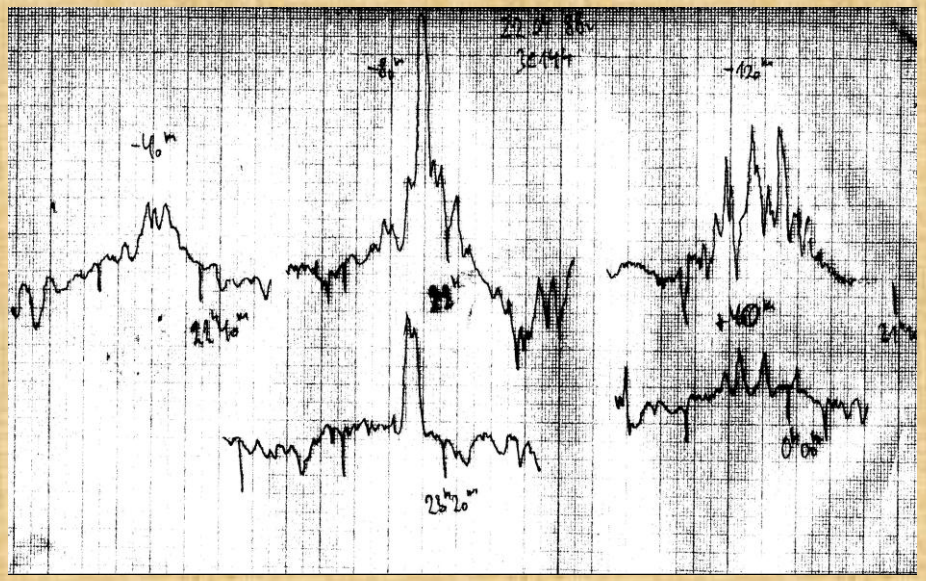
**The size of a zone having tidel waves reaches 60 angular degrees.**

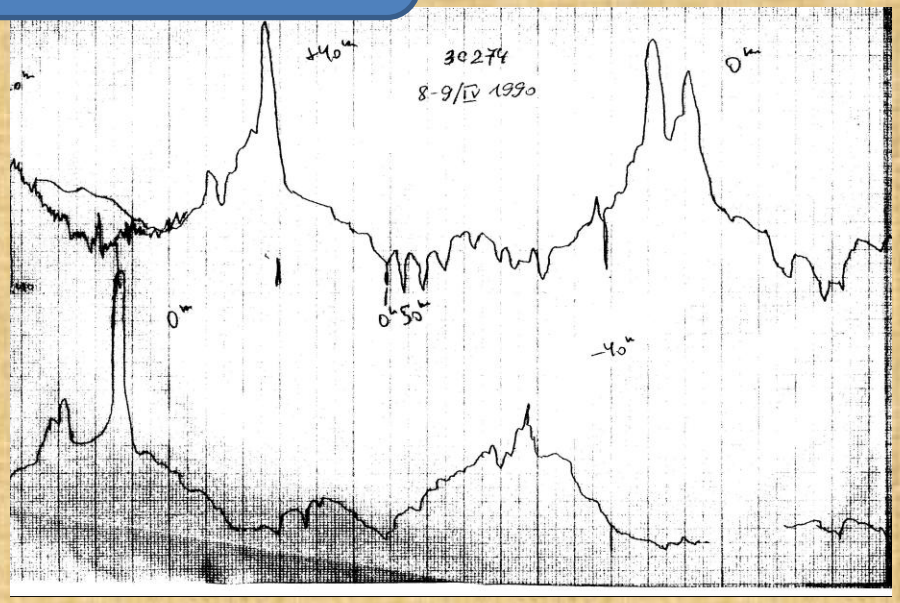
# Moon tides

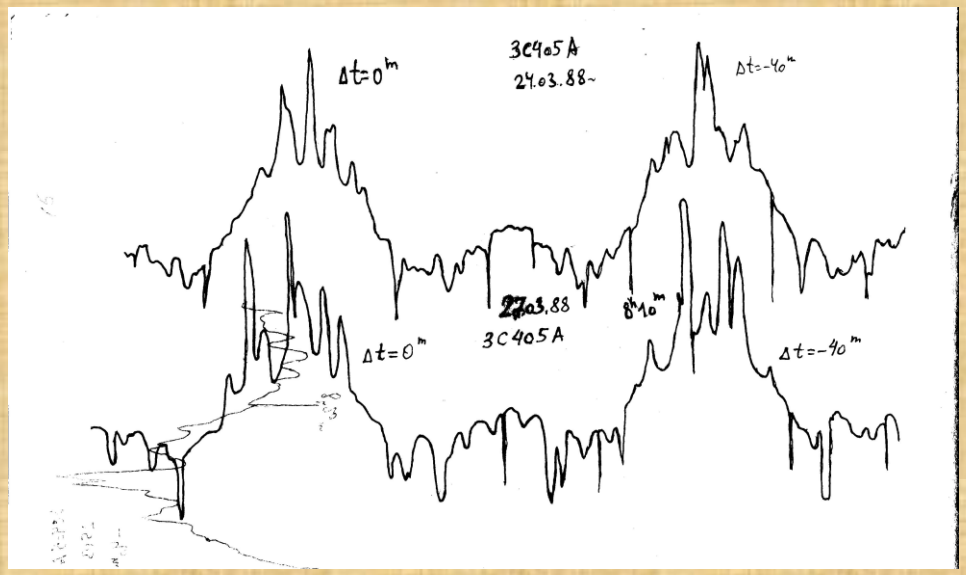
# Effect tide modulation

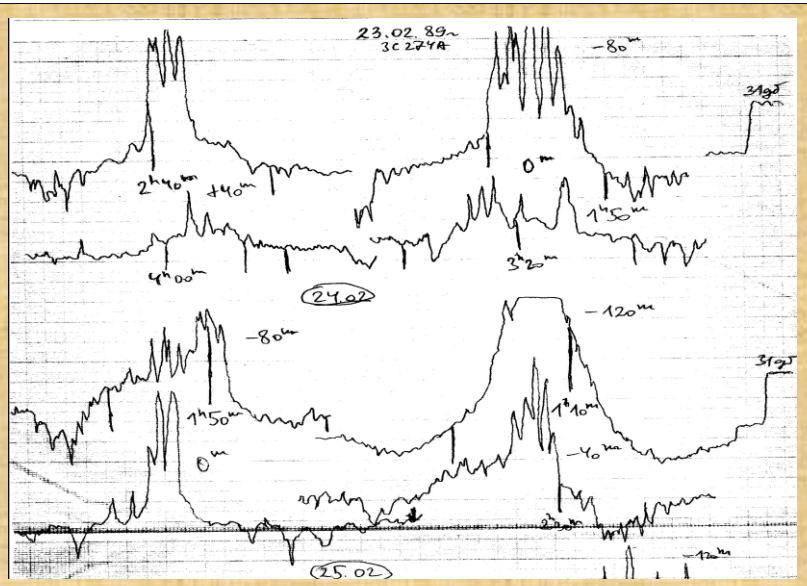


# Records effects moon tides

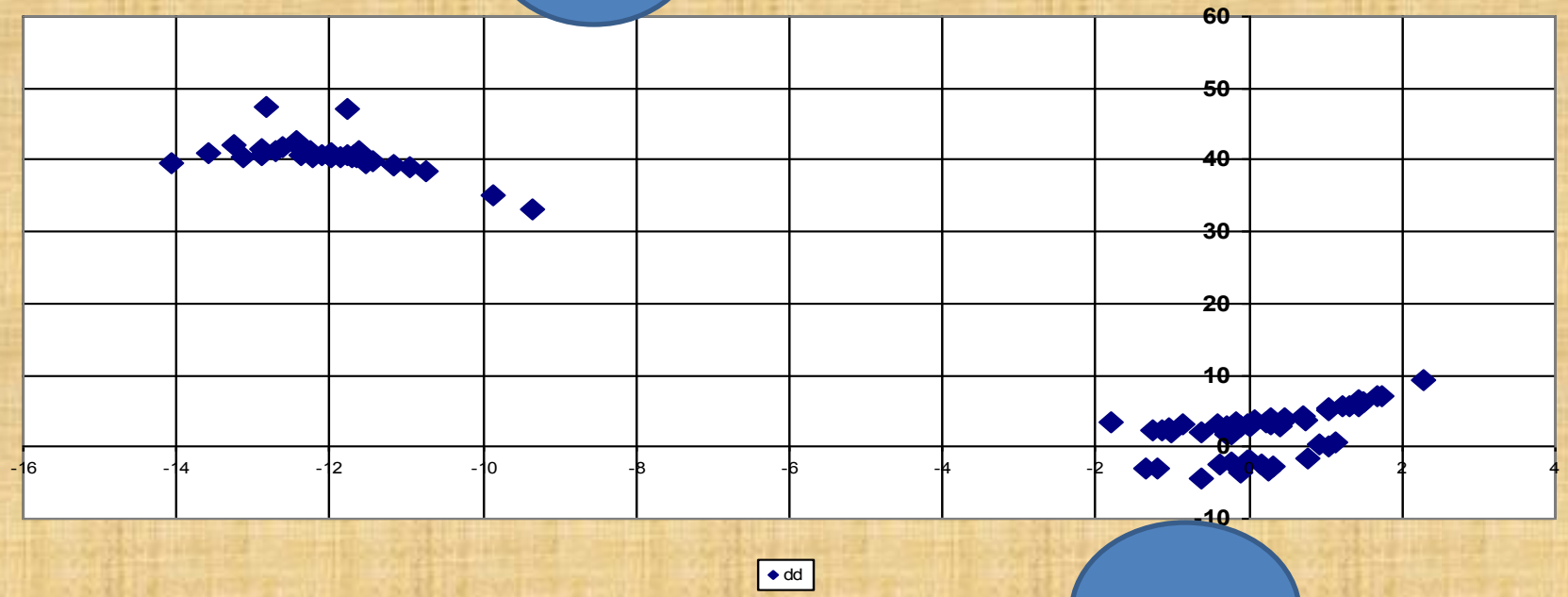




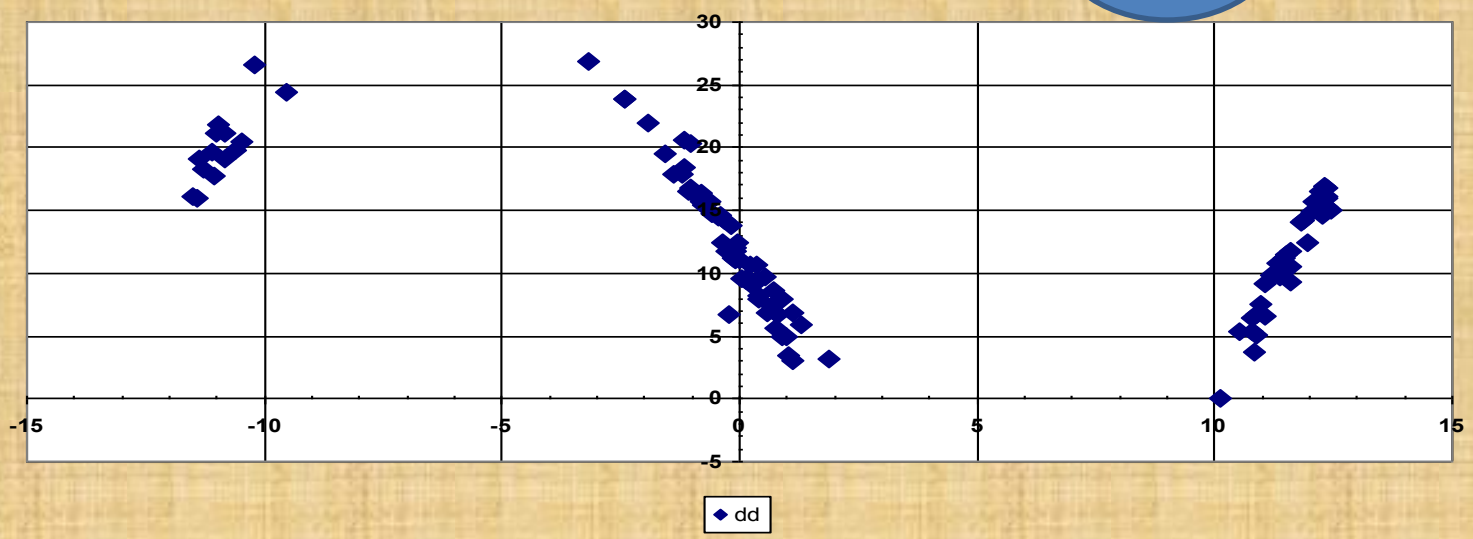



Tau A


3C144dd-da
60
50
40
30
20
10
0
-10
-16
-14
-12
-10
-8
-6
-4
-2
0
2
4
dd

Vir A


3c274dd-da
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20
15
10
5
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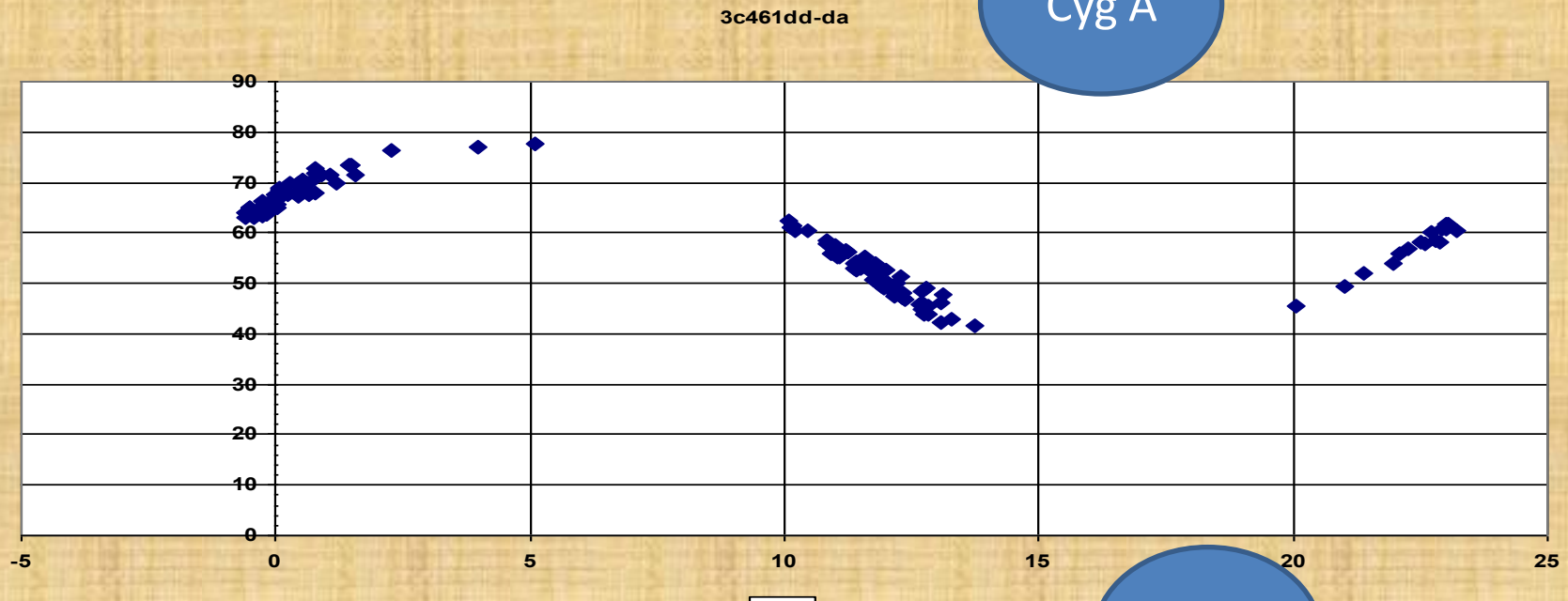
-5
-15
-10
-5
0
5
10
15
dd

Cyg A


3c461dd-da
90
80
70
60
50
40
30
20
10
0
-5
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5
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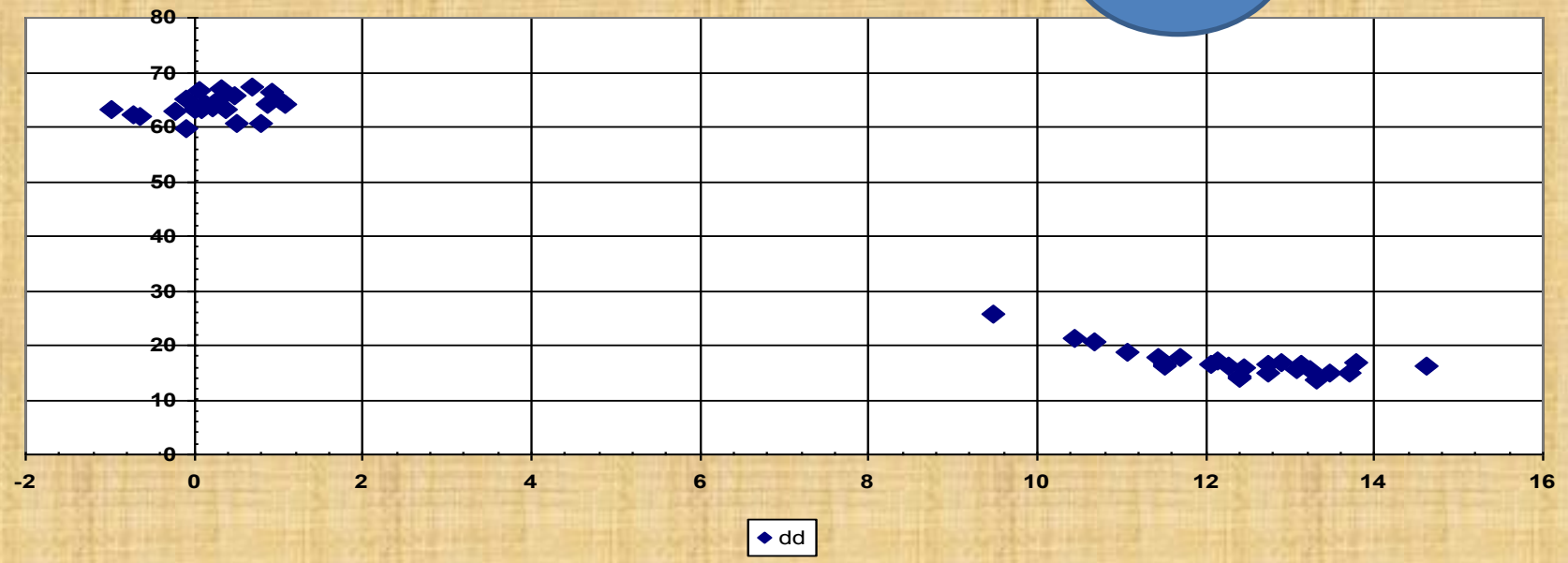
25
dd

Cas A


3c405dd-da
80
70
60
50
40
30
20
10
0
-2
0
2
4
6
8
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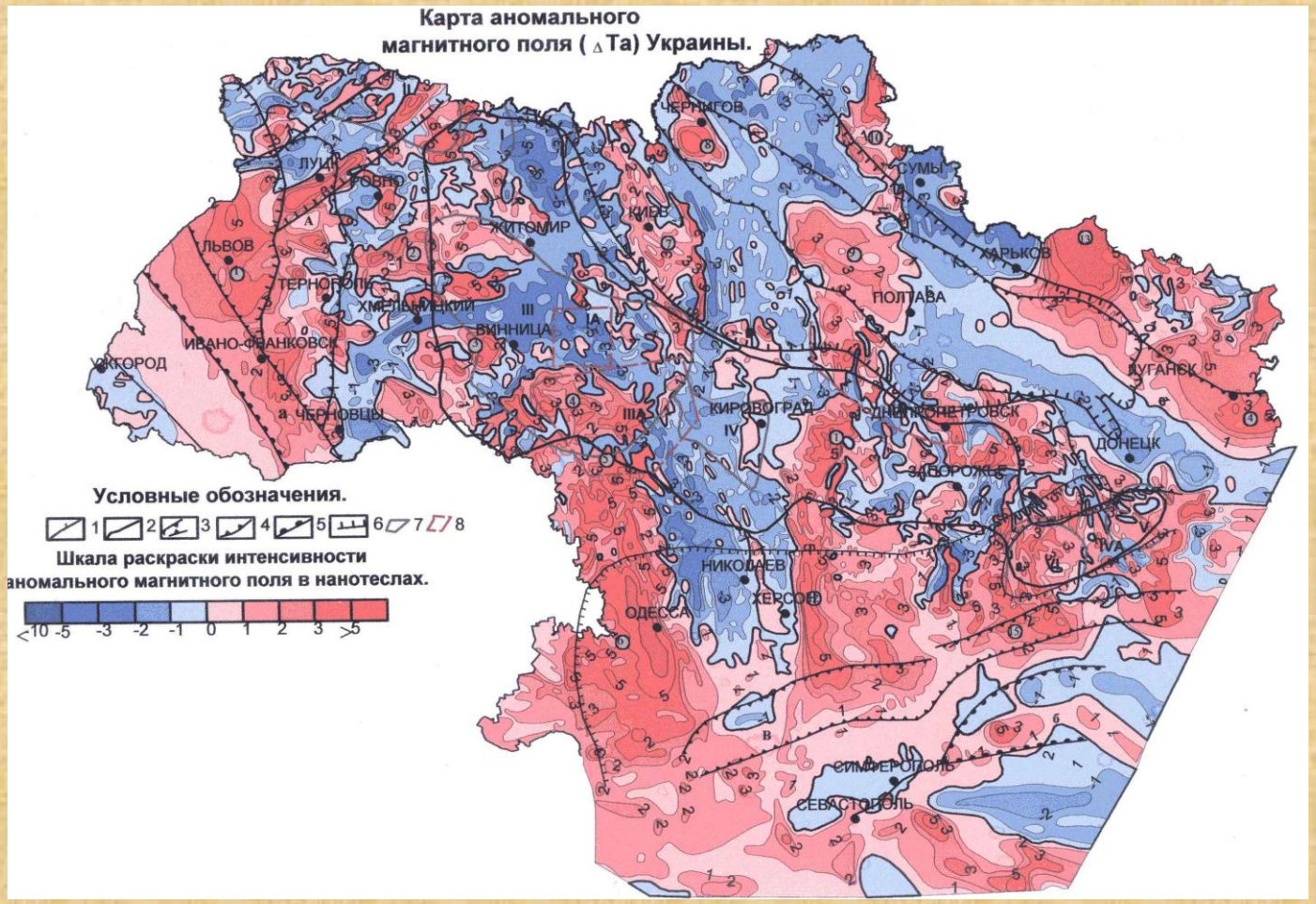
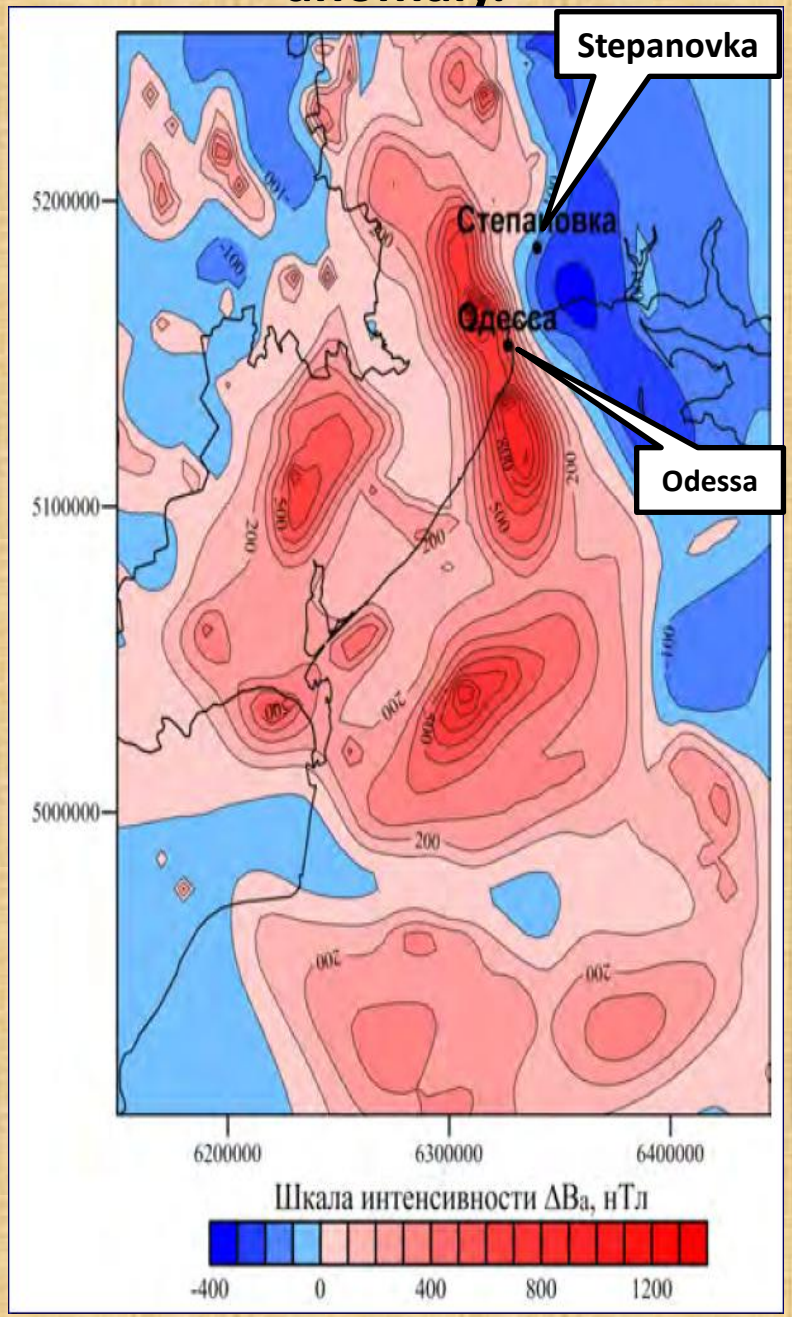
12
14
16
dd

# The magnetic observatory "Odessa" is situated near the intensive magnetic anomaly

**The identification of the magnetic anomaly influence on geomagnetic activity comparison of characteristics of magnetic storms in Odessa and Moscow was carried out**



# Odessa regional magnetic anomaly.




region and Odessa city was first investigated in 1892.

Due to significant influence of ionosphere state on conditions of observations cosmic radio sources in the Odessa Observatory "URAN-4" (decameter radio telescope (phased array), frequency range 10 - 30 MHz), direct measurements of geomagnetic field variations at center of magnetic anomaly will make it possible to clarify physical causes of observed systematic effects in fast and slow changes in the flux density of radio sources over

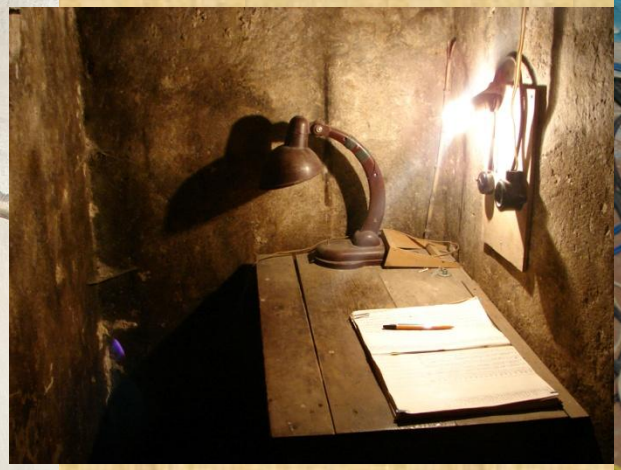
Anomalous magnetic field of the region under study changes from -400 nT in eastern part of the Odessa region to +1200 nT in its central part. Model sources of anomalies consists from blocks with vertical and inclined lateral faces, at depths from 1-7 km (sources of local anomalies) and 7-40 km (sources of regional anomaly). The magnetization of the blocks varies from 0.7 A / m for the background source to 3.5-4 A / m directly for sources of anomaly. There is a secular increase in induction of the geomagnetic field.

In the figure, the calculated geomagnetic field of sources in the Odessa magnetic anomaly

# Magnetic observatory "Odessa“

The magnetic observatory "Odessa" was founded by the Novorossiysk Imperator University, in the territory of a botanical garden, at the beginning of the XX century. In 1936 it was transferred to the village of Stepanovka (near Odessa) by the Odessa State University. After world war 2th the station became to belong to the Institute of geophysics NAS Ukraine.

Since 1948 measurements of a magnetic field of Earth, with a time frame – are conducted 1 hour. At the same time measurements of three elements of a magnetic field are registered: horizontal component (H), vertical component (Z) and inducement (D).



# The comparison duration of the magnetic storms in Odessa and Moscow (total for the year)

# Instrument and methodology for analyzing observational data.


To study fast variations of geomagnetic field in central region of the magnetic anomaly, a precision fux-gate three-component magnetometer LEMI-008 (developed by the Space Research Institute of the National Academy of Sciences of Ukraine) was used. For protection against electromagnetic interference the device is installed in cellar of the Odessa Astronomical Observatory.

The range of measurement of variations is +/- 100,000 nT (1), +/- 3200 nT (2). The resolution is 10 nT (1), 0.1 nT (2).The noise level in the analog channel (0.1-1 Hz) is less than 10 pT. The averaging measurements time is 1, 2, 5, 10, 60 seconds. Long-term zero drift +/- 5 nT per year. Correction of time and position by GPS signals.

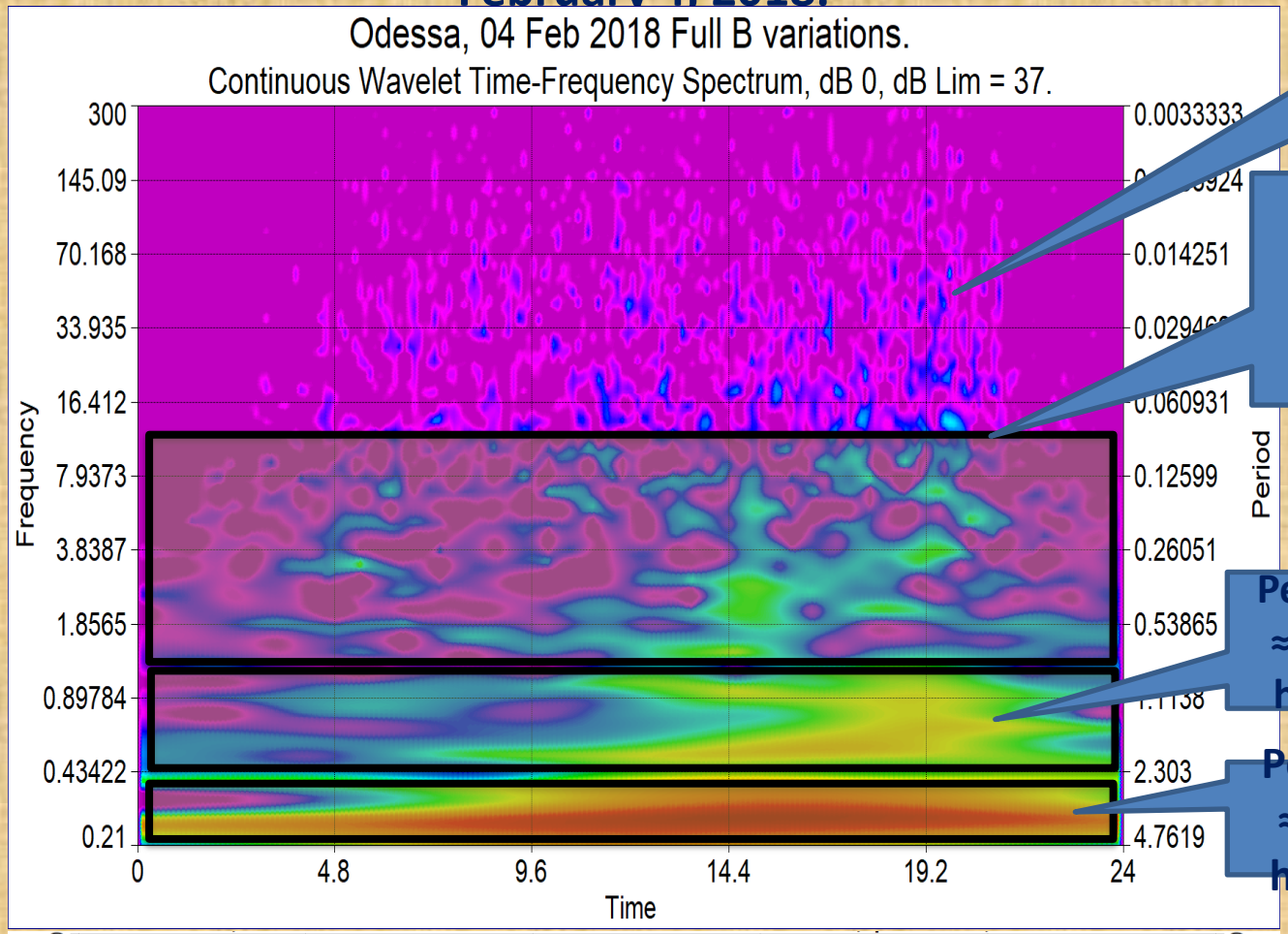
Electronics unit

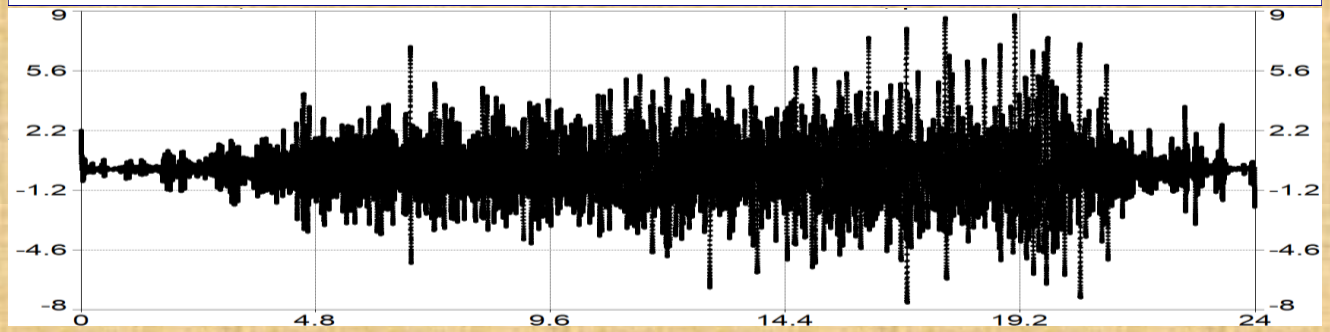
Observations with 1 second resolution were carried out from November 2017 to April 2018.

Three-axis flux-gate sensor

To calculate the time-frequency spectra, a fast version of continuous wavelet transform is used, as well as band-pass filtering based on it. When studying oscillations in the period band about minute and little less, FFT interpolation was applied beforehand for upsampling data.

# Example of wavelet spectrum of variations geomagnetic field vector modulus in the Odessa magnetic anomaly, February 4, 2018.




Area of overlap of irregular and short-term pulsations, periods ≈ 1 - 5 minutes

Area of quasiharmonic pulsations, periods ≈ 6 - 40 minutes

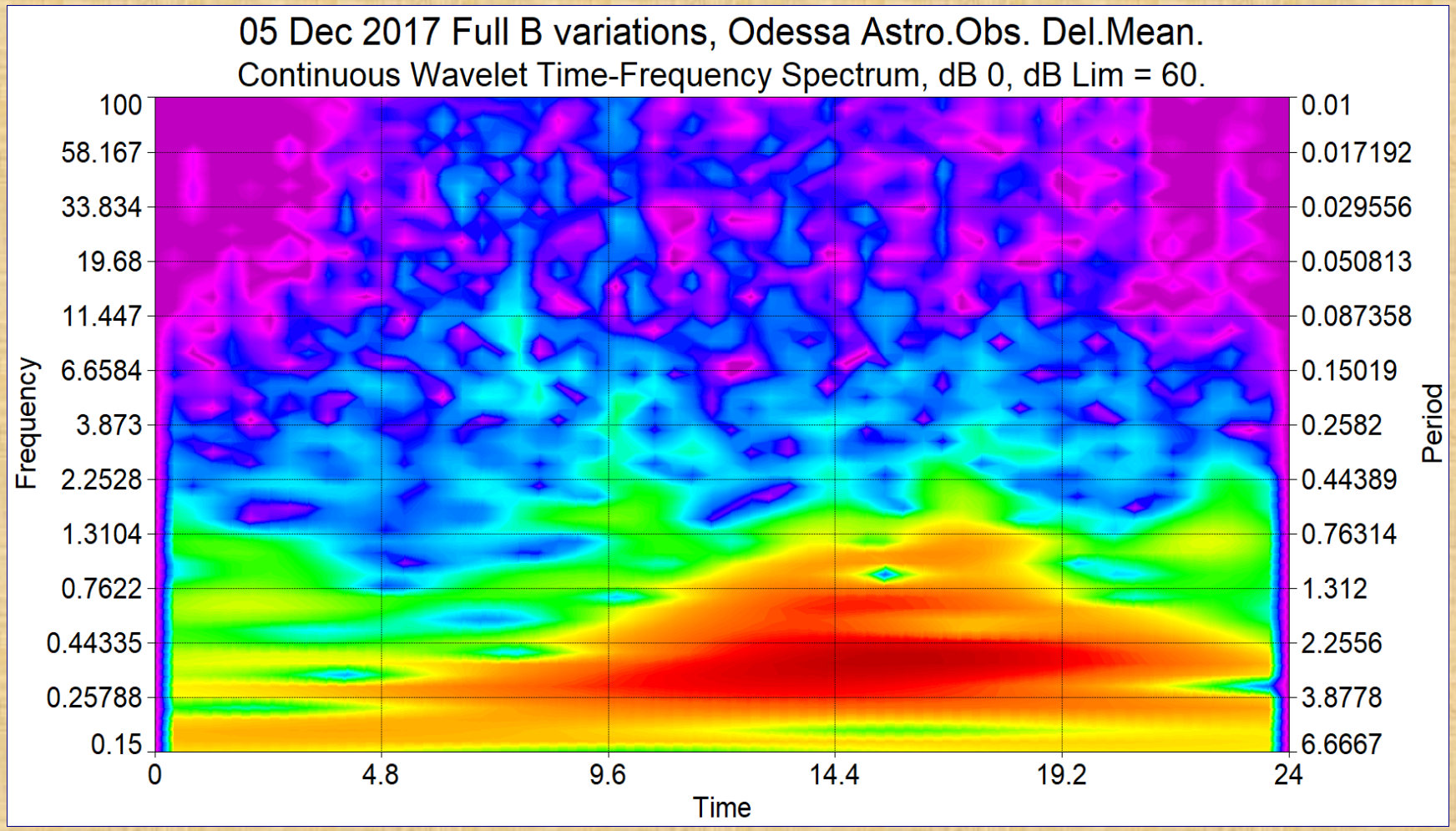
Periods ≈ 1 - 2 hours

Period ≈ 3.7 hours

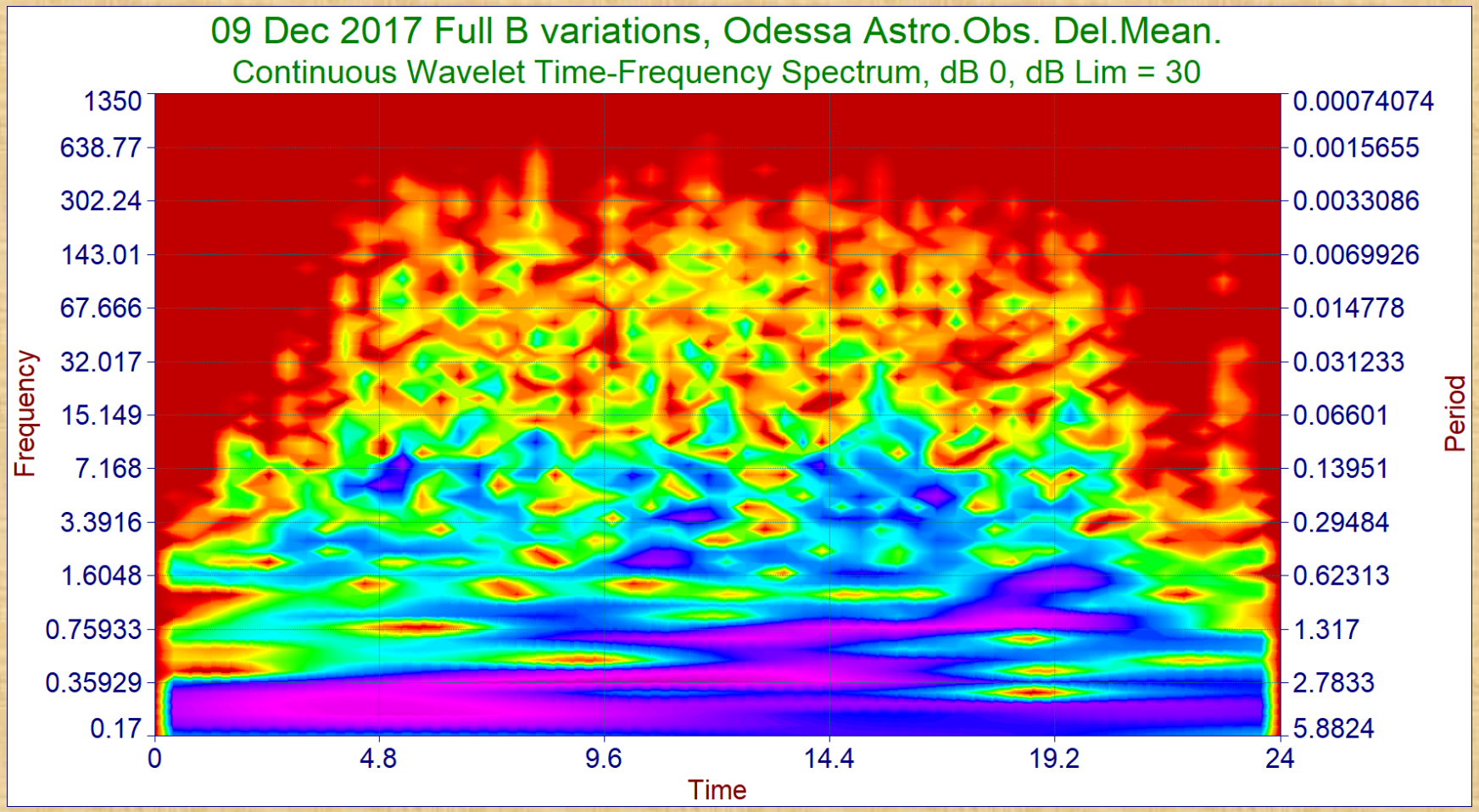
ple of a typical wavelet spectrum of a magnetic storm in the Odessa regional magnetic anomaly is shown. In this figure: the spectrum in decibels, normalized to 0; Time, Period - in hours; Frequency - the number of

Induction amplitude variation in the period band 1 - 5 minutes (subtracted mean value)

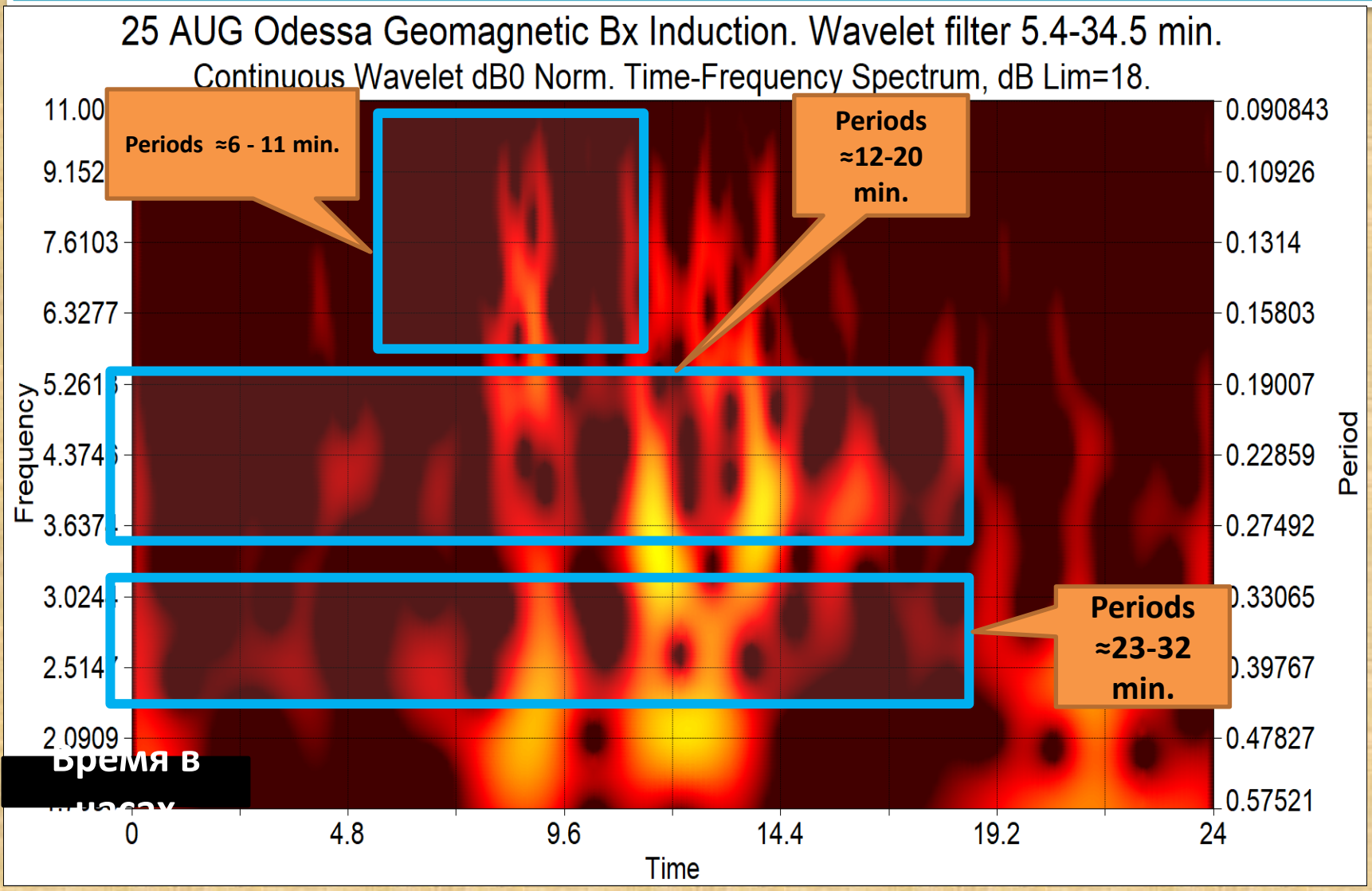
# Waivelet spectrum of perturbation during a magnetic storm in Odessa.



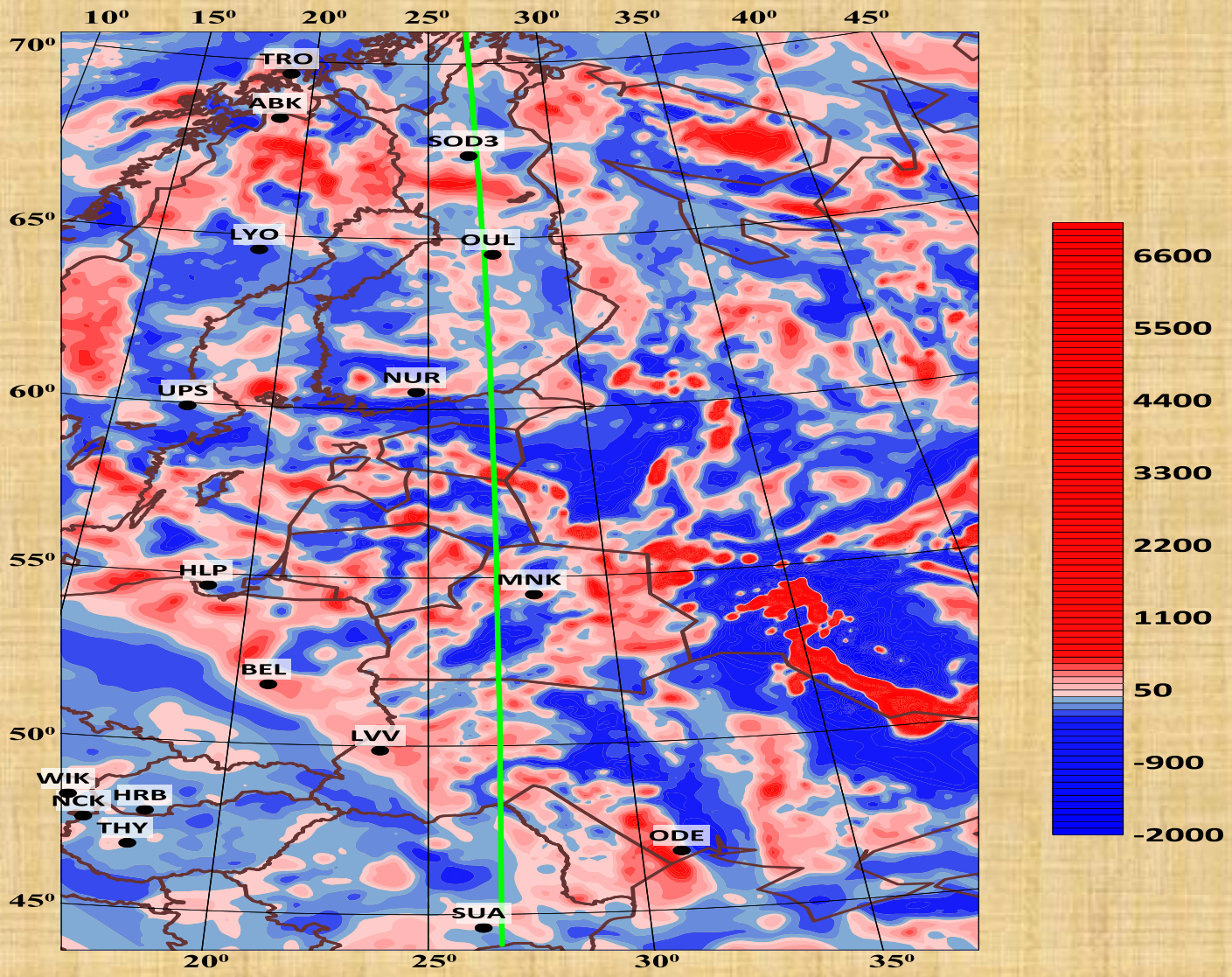
# Waivelet spectrum of quite state of geomagnetic field in Odessa



**The vaivelet spectrum of geomagnetic variations in the band of periods from 5.4 to 34.5 minutes during a powerful magnetic storm on August 25, 2018 in the zone of the Odessa magnetic anomaly.**



# Geomagnetic field in "Struve Arcs".



# Basic data for project development

- **The results of monitoring of powerful radio sources (fluxes and flickers) on the radio telescope "URAN-4" from 1987 to the present time at frequencies of 20 and 25 MHz.**
- **Catalog of magnetic storms of the observatory "Odessa" since 1987.**
- **Data variations of the components of the geomagnetic field with an interval of 1 hour at the magnetic observatories Odessa, Kiev, Lviv from 1950 to the present.**

- **The results of registration of the perturbation of the geomagnetic field in the zone of the magnetic anomaly in Odessa in 2017-2019.**

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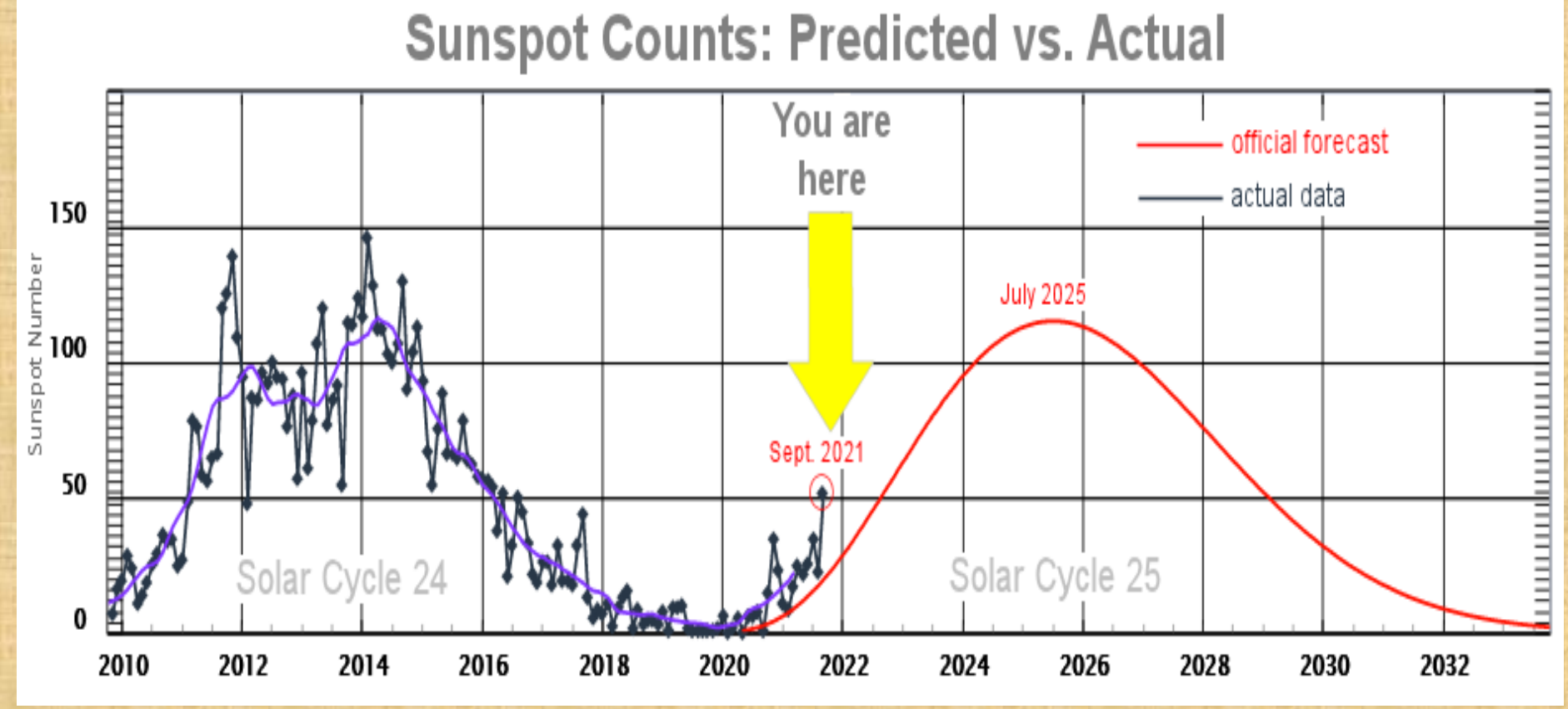
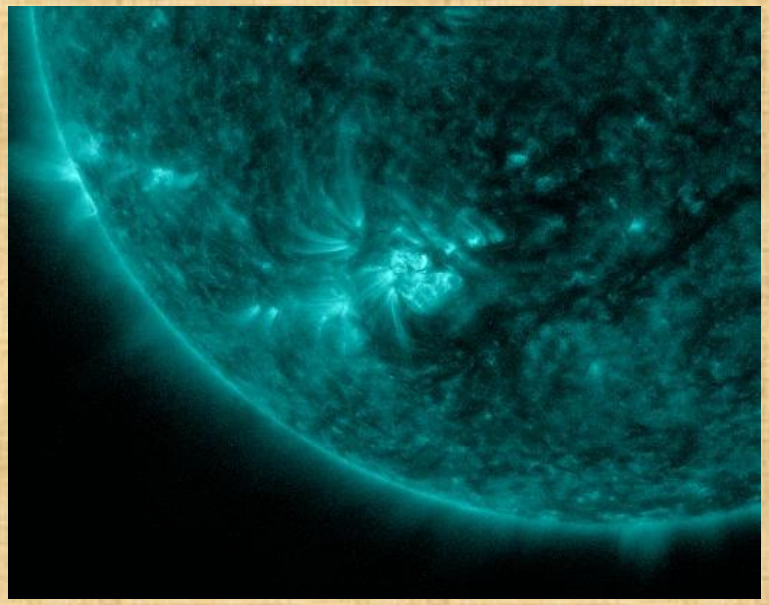
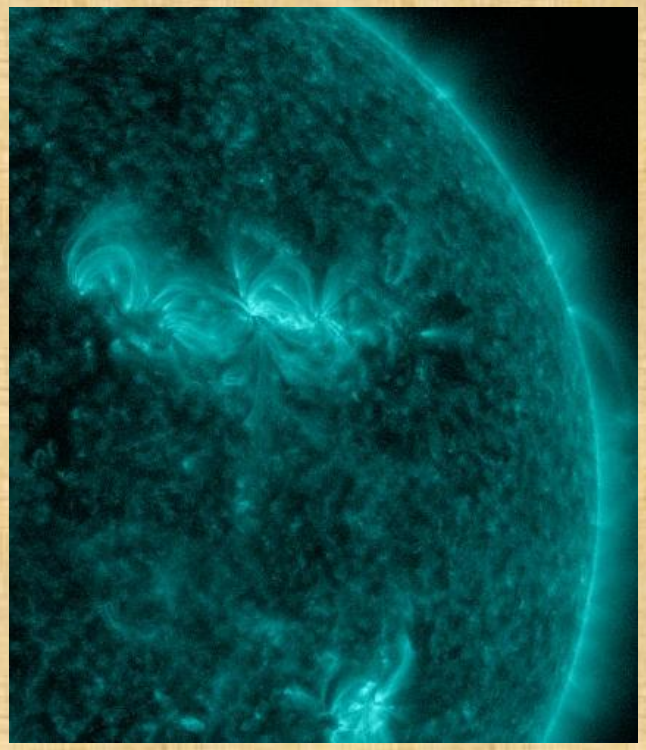
# Conclusion

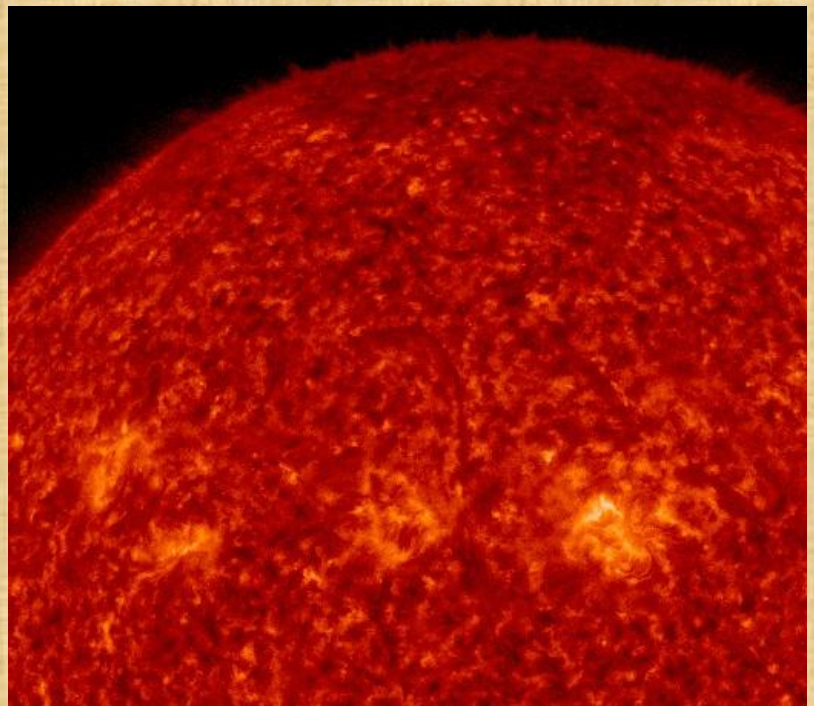
- In the project, for research response of space “Struve arc” to Solar activity, will use existing basis of joint Latvian-Ukrainian cooperation, in form of long-term monitoring ionospheric scintillations of powerful space radio sources (over Latvia and Ukraine), and monitoring geomagnetic variations in areas of normal and anomalous magnetic field of the Earth (including Latvia), it is planned to study in detail manifestation “space weather”, during growth phase and maximum of the 25th cycle Solar activity.

# 25 solar cycle

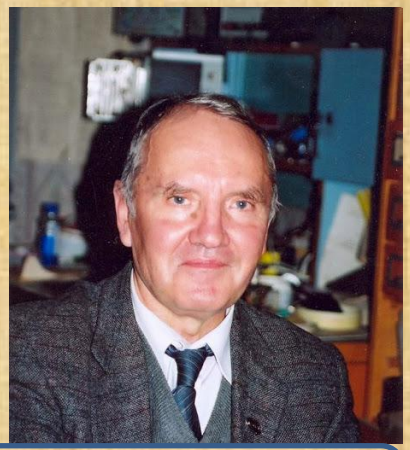






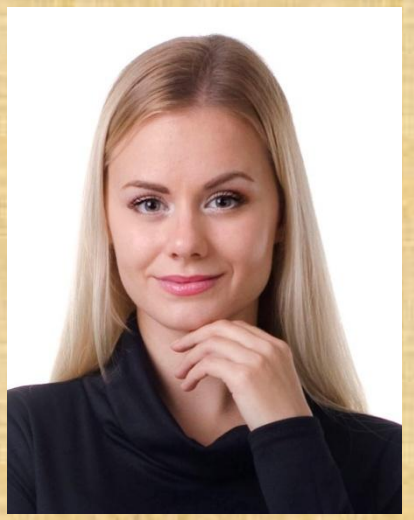


# Our research team in Radio-astronomical Institute and cooperation



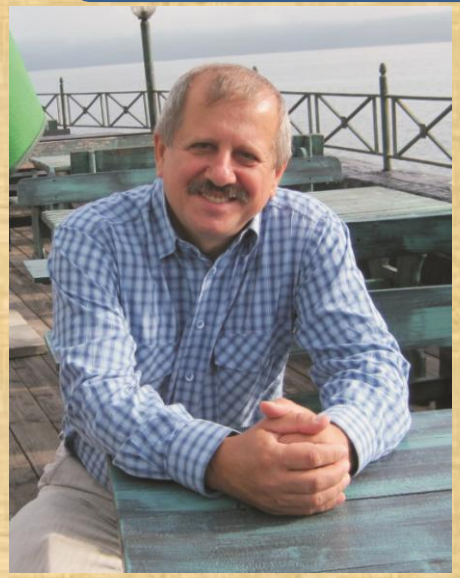
Head – Dr.Michail Ryabov

Dr. Artem Sukharev



Luba Sobitniak
Junior Staff Scientist

Vladimir Komendant
leading engineer-radiophysicist



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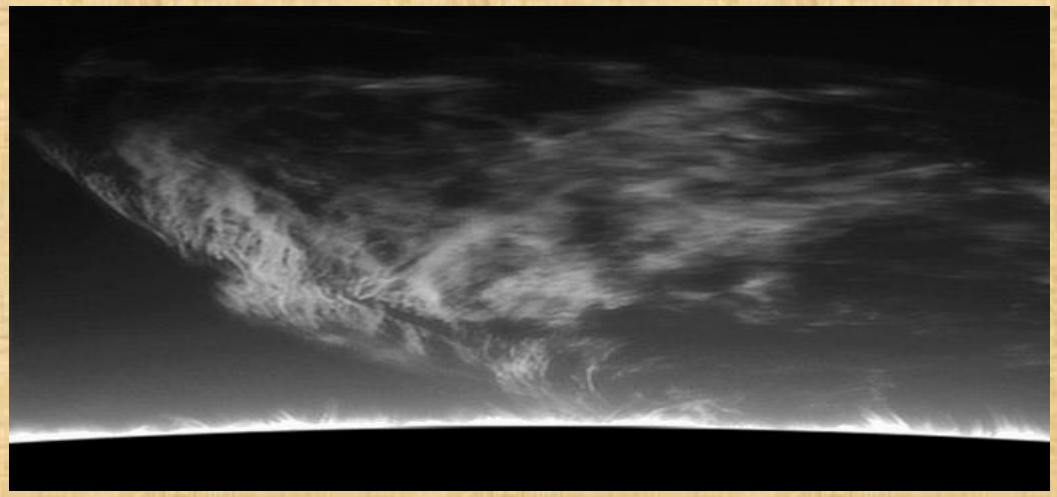
# Invitation the XXII Gamow astronomical online conference in Odessa from 15 to 20 August 2022 (www.gamow.odessa.ua)



# Thank you!

**Solar activity is increasing.**

**I wish high activity of the Conference in Zolochiv!**