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PostDoc Latvia

# *Perspectives of monitoring research on radio telescopes from millimeter to decameter wavelengths to solve fundamental and applied problems.*

RT-32 Zolochiv: First Results, EU Collaboration, Radio Astronomy Frontiers

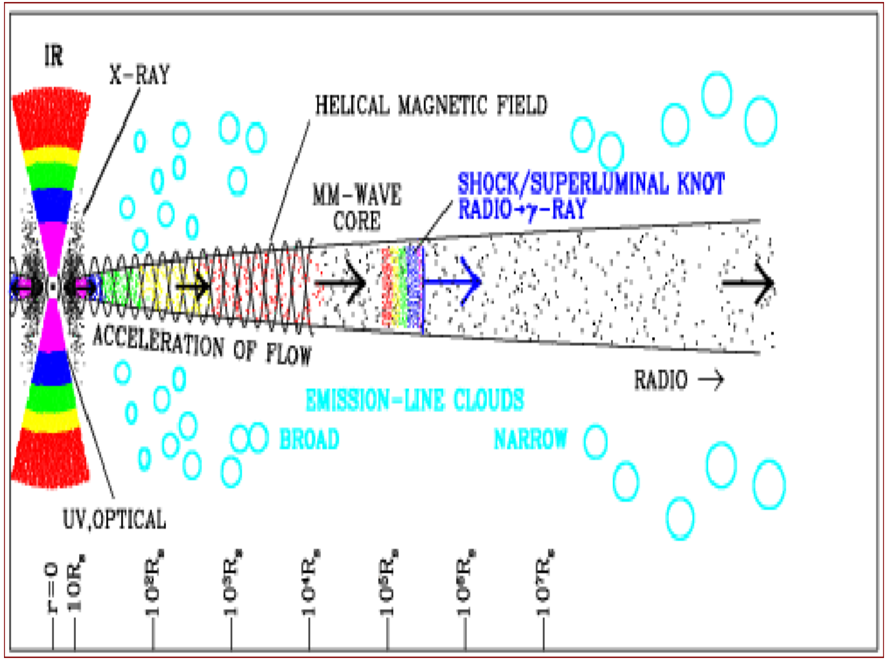
Investigation of intra-day and inter-day variability of various types of extragalactic radio sources using telescopes of the Ventspils International Radio Astronomy Centre (RISE). Project no.: 1.1.1.2/VIAA/2/18/363

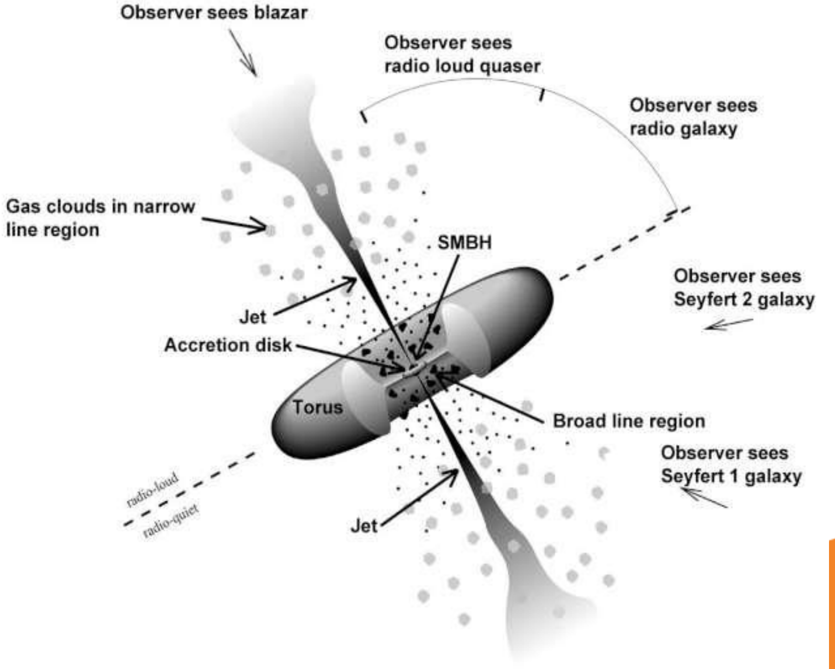
Valsts izglītības attīstības aģentūra
NACIONĀLAIS ATTĪSTĪBAS PLĀNS 2020
EIROPAS SAVIENĪBA
Eiropas Reģionālās attīstības fonds
IEGULDĪJUMS TAVĀ NĀKOTNĒ

# Content report

- Daily and intraday monitoring of the variable fluxes  of active galaxies nuclei at RT -32 and RT-16 Ventspils International Radioastronomical Centre.
- The results of long-term monitoring of fluxes of powerful space radio sources at RT "URAN-4" of the Odessa Observatory RI NASU and space weather.
- Perspectives of monitoring research on radio telescopes from millimeter to decameter wavelengths to solve fundamental and applied problems.

# Models of active galactic core



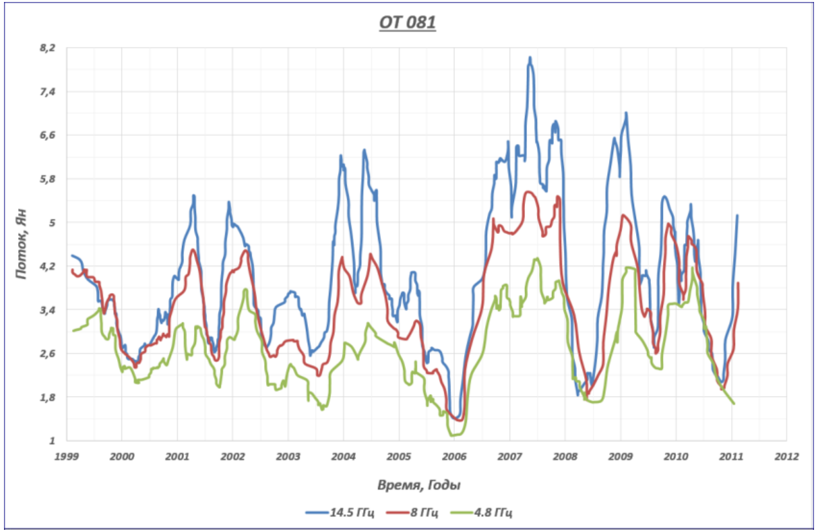



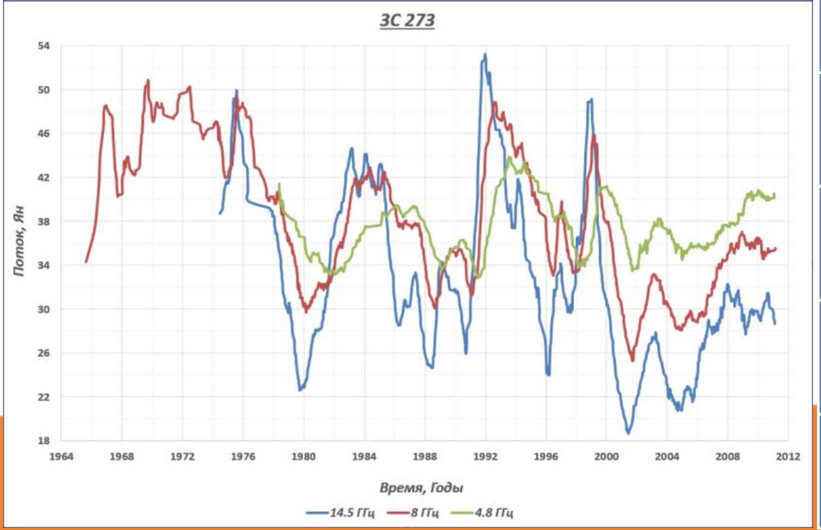

PostDoc Latvia

# Analysis 40-years long-term monitoring in Radio-observatory of Michigan University (collaboration with M.Aller)

- 26 meter radiotelescope
- Frequence 4.8, 8  and 14.5 GHz

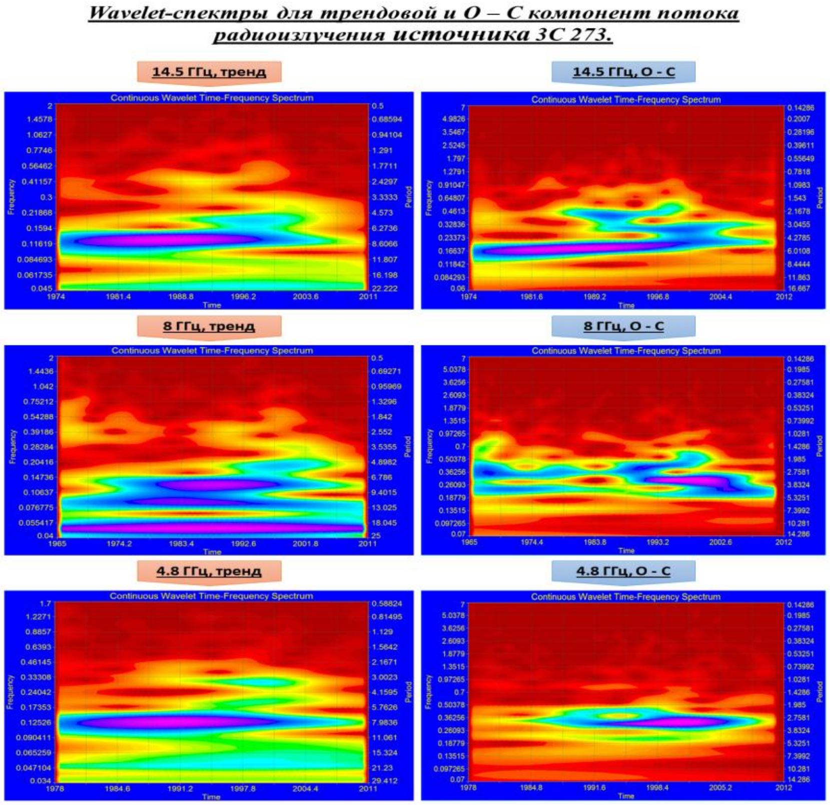
PostDoc Latvia

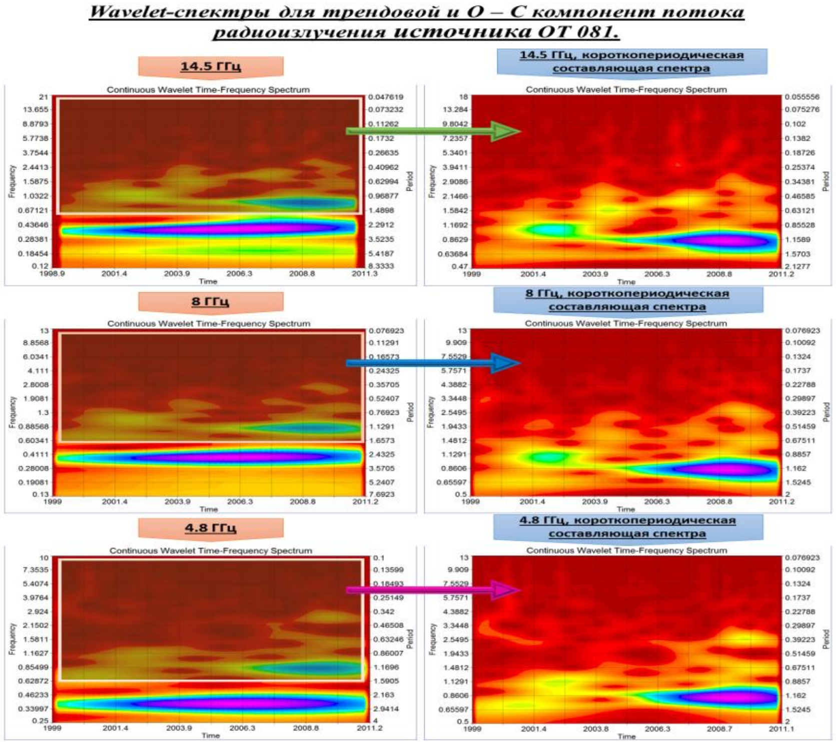



| Source | Fr., GHz | Time int. | Count | Mean, Jy | Min, Jy | Max, Jy | Err, Jy | Std.Dev. |
|---|---|---|---|---|---|---|---|---|
| 3C 273 | 14,5 | 1974.4 - 2011.1 | 1429 | 31,28 | 18,33 | 53,95 | 0,36 | 7,88 |
| | 8 | 1965.6 - 2011.1 | 1738 | 37,54 | 24,71 | 51,95 | 0,43 | 5,95 |
| | 4,8 | 1978.4 - 2011.0 | 1025 | 37,24 | 32,78 | 44,56 | 0,30 | 2,55 |
| 3C 120 | 14,5 | 1974.6 - 2011.0 | 1096 | 3,21 | 1,60 | 11,77 | 0,06 | 1,27 |
| | 8 | 1966.7 - 2011.1 | 1182 | 4,57 | 1,84 | 15,30 | 0,08 | 2,48 |
| | 4,8 | 1980.3 - 2009.7 | 629 | 3,74 | 2,21 | 5,55 | 0,08 | 0,70 |
| 3C 345 | 14,5 | 1974.4 - 2011.1 | 1289 | 8,68 | 4,50 | 17,48 | 0,13 | 2,71 |
| | 8 | 1965.7 - 2011.1 | 1196 | 9,50 | 4,62 | 16,05 | 0,12 | 2,61 |
| | 4,8 | 1978.4 - 2011.0 | 1094 | 8,51 | 5,11 | 13,12 | 0,10 | 2,03 |
| 3C 446 | 14,5 | 1979.9 - 2011.1 | 949 | 6,33 | 2,90 | 10,37 | 0,08 | 1,66 |
| | 8 | 1979.0 - 2011.1 | 752 | 5,86 | 3,04 | 8,95 | 0,08 | 1,45 |
| | 4,8 | 1980.4 - 2011.1 | 603 | 5,36 | 3,53 | 8,20 | 0,09 | 1,07 |
| 3C 454.3 | 14,5 | 1974.2 - 2011.1 | 1558 | 10,05 | 5,11 | 28,04 | 0,13 | 3,86 |
| | 8 | 1966.6 - 2011.1 | 1529 | 12,30 | 6,51 | 26,91 | 0,14 | 3,73 |
| | 4,8 | 1978.5 - 2011.1 | 885 | 11,70 | 7,61 | 17,16 | 0,13 | 2,06 |
| OJ 287 | 14,5 | 1974.5 - 2011.1 | 1121 | 3,81 | 1,25 | 9,97 | 0,08 | 1,72 |
| | 8 | 1971.1 - 2011.1 | 936 | 3,47 | 1,15 | 7,67 | 0,07 | 1,37 |
| | 4,8 | 1979.3 - 2011.0 | 766 | 2,44 | 1,05 | 4,57 | 0,07 | 0,80 |
| BL LAC | 14,5 | 1974.2 - 2011.1 | 1441 | 3,56 | 1,50 | 15,46 | 0,06 | 1,60 |
| | 8 | 1968.1 - 2011.1 | 1138 | 4,18 | 1,67 | 13,33 | 0,08 | 2,01 |
| | 4,8 | 1979.3 - 2011.1 | 1010 | 3,41 | 1,70 | 10,22 | 0,06 | 1,23 |
| OT 081 | 14,5 | 1999.1 - 2011.1 | 707 | 4,10 | 0,90 | 8,36 | 0,06 | 1,42 |
| | 8 | 1999.1 - 2011.1 | 364 | 3,46 | 1,20 | 5,93 | 0,07 | 0,11 |
| | 4,8 | 1999.1 - 2011.0 | 409 | 2,72 | 0,64 | 5,31 | 0,07 | 0,82 |

# Wavelet time-frequency spectra for 3C273 and OT081

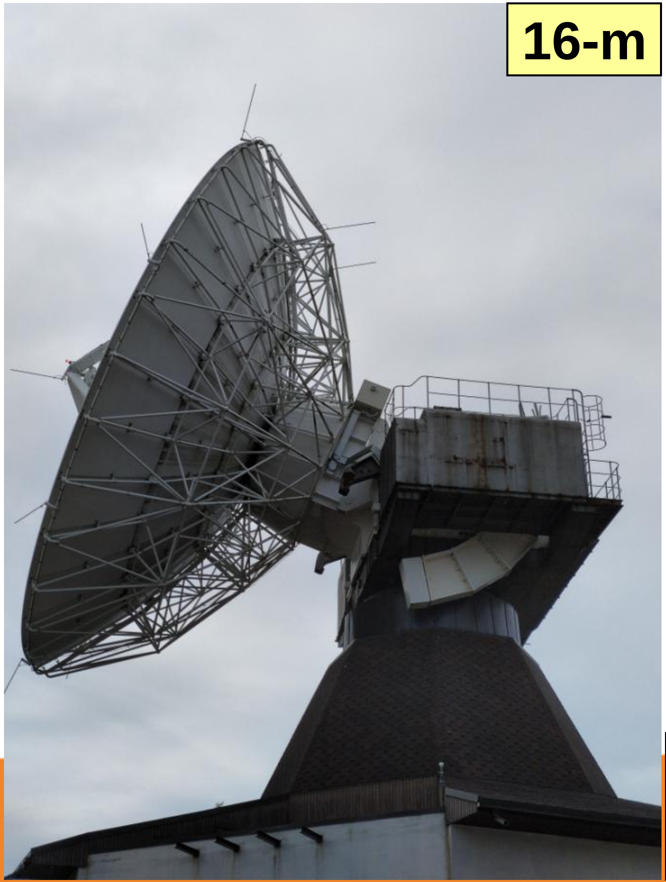


# DAILY AND INTRADAY MONITORING OF THE VARIABLE FLUXES  OF ACTIVE GALAXIES NUCLEI AT RT-32 AND RT-16 VENTSPILS INTERNATIONAL RADIOASTRONOMICAL CENTRE.

PostDoc Latvia

**Ventspils International Radio Astronomy Center in Latvia now operating with two parabolic radio telescopes (32-m and 16-m dish diameters). Observations are carried out at frequencies 1.6, 5, 6.1, 6.7, 8.4 GHz.**

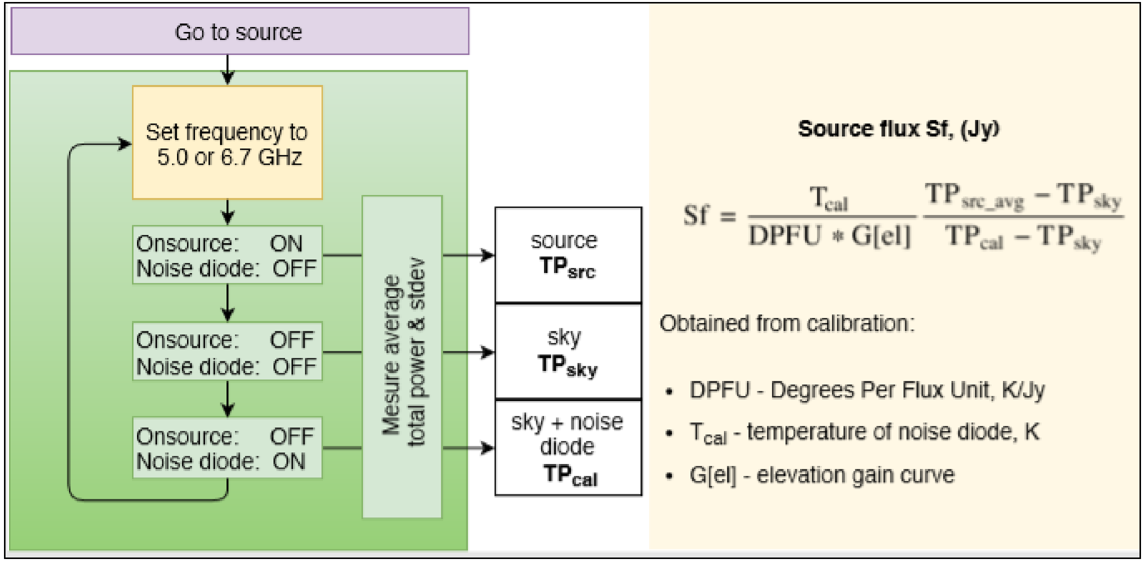


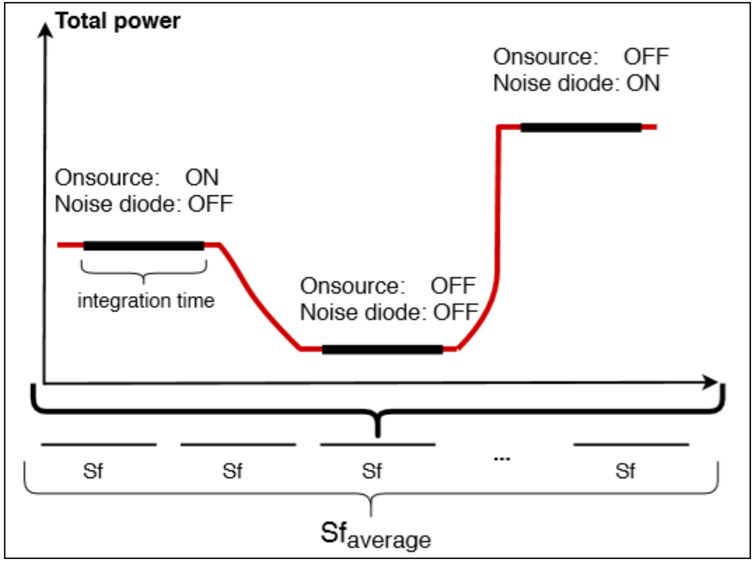


**Both radio telescopes participate in observations AGN as part of European interferometric network (EVN).**

PostDoc Latvia

# Scheme for obtaining flux density points at the 16-m and 32-m VIRAC radio telescopes




**Calibration sources 3C 196, 3C 286, 3C 123 are used to check stability of receiving equipment and compare with variable radio sources. Observations are performed in two modes, hi-speed and normal (with internal averaging and using multiple calibration sources), this allows to get from 100 to several thousand flux points per day.**

**Two circular polarizations are used, left (LCP) and right (RCP).**

# Joint observations (2019) radio source OJ 287 in radio (VIRAC telescopes) and optical range (Odessa observation station Mayaki, Ukraine ; Baldone, Latvia ; Vihorlat, Slovakia)

Ukraine, AZT-3, 48 cm

Slovakia, VNT, 1-m

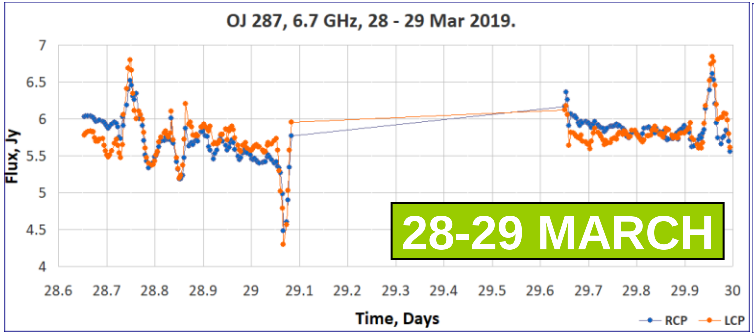
Latvia, Schmidt camera, 1.2-m

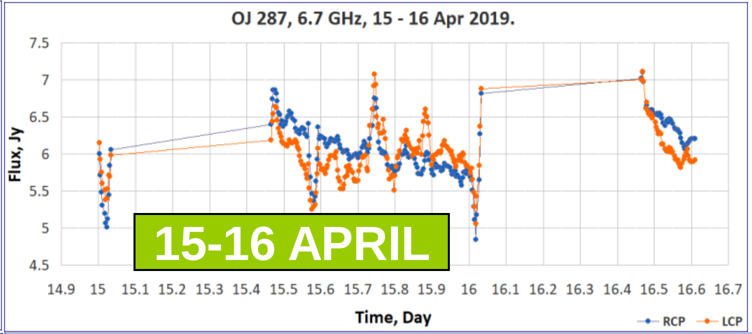
**Observations made in filters V, R, I**

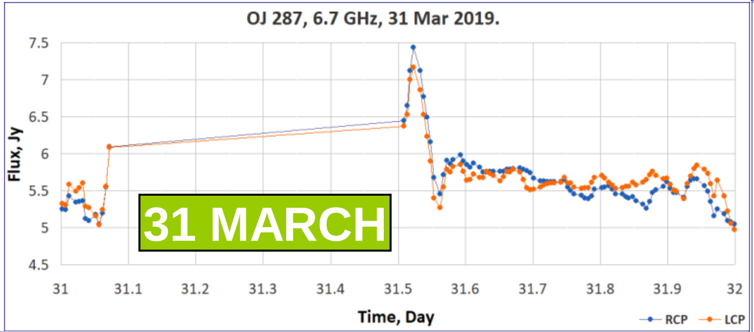
PostDoc

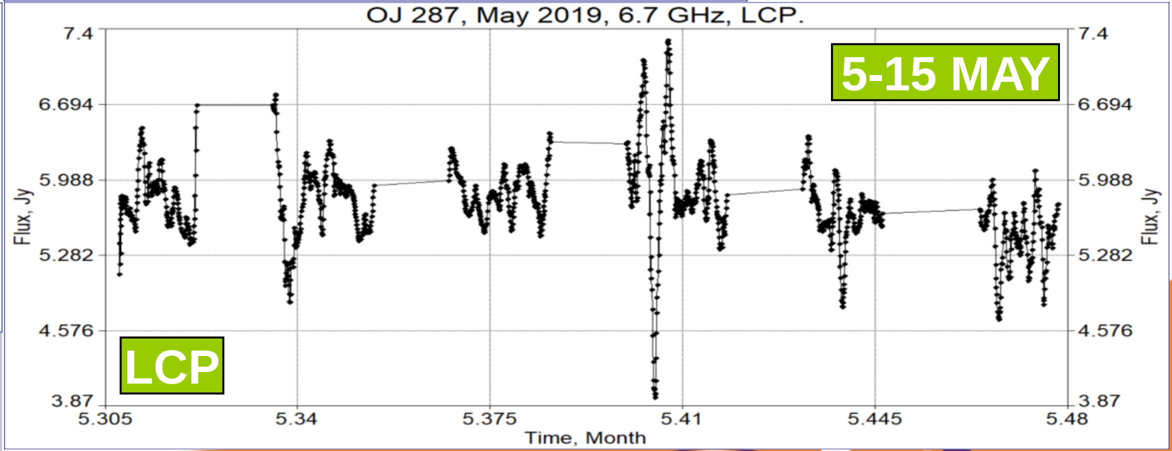
# Examples of variations in flux density OJ 287 for individual observation sessions in 2019.

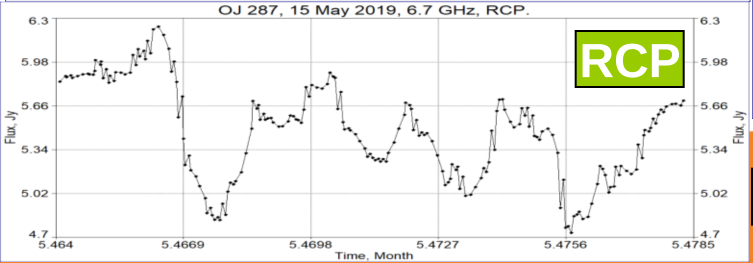
**Examples show that IDV form of variations rapidly changes on different days of observation. Sometimes flux can be almost constant.**



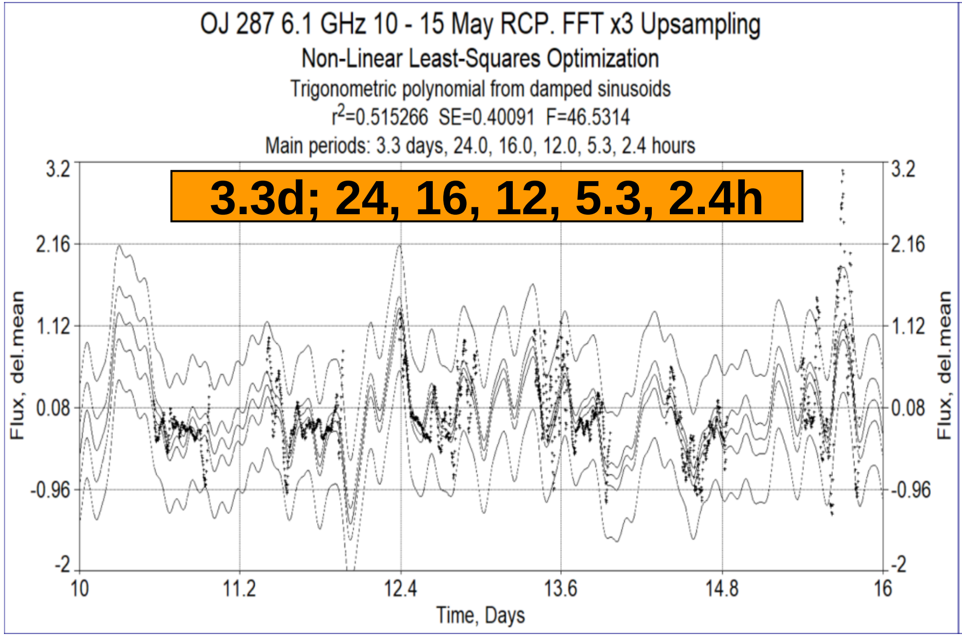



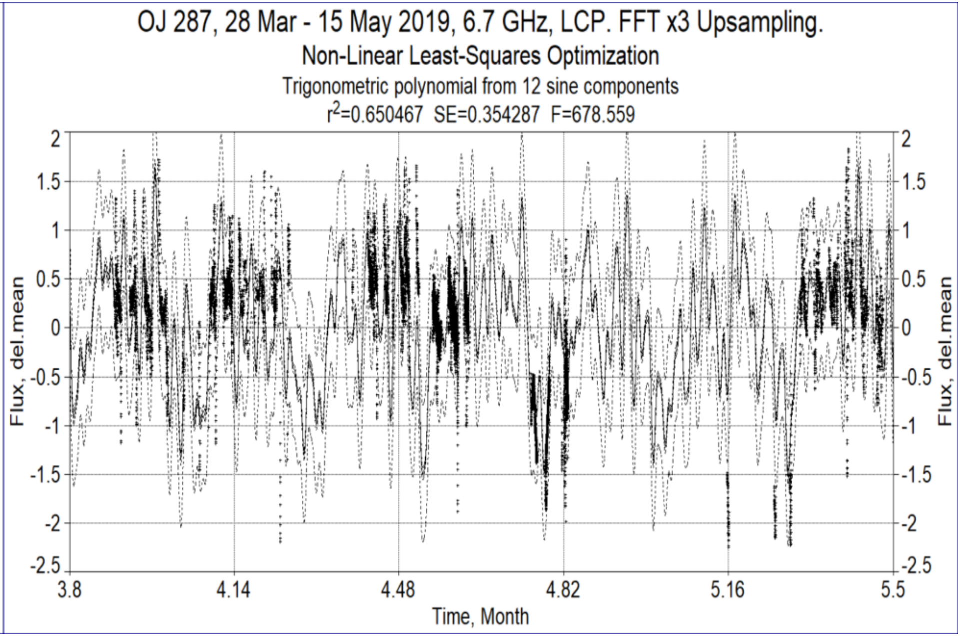




15 MAY

PostDoc Latvia

# Fast variability of OJ 287 at frequencies of 6.1, 6.7 GHz.




**Examples of trigonometric polynomials based on maxima of Least-Squares periodogram, with refinement by Levenberg-Marquardt iterative method. For frequency 6.1 GHz, 6 sine waves were used, for frequency 6.7 GHz - 12 sine waves. Strong diurnal modulation of flux density is clearly visible (probably due to quasiperiodic repeat of gaps in data).**

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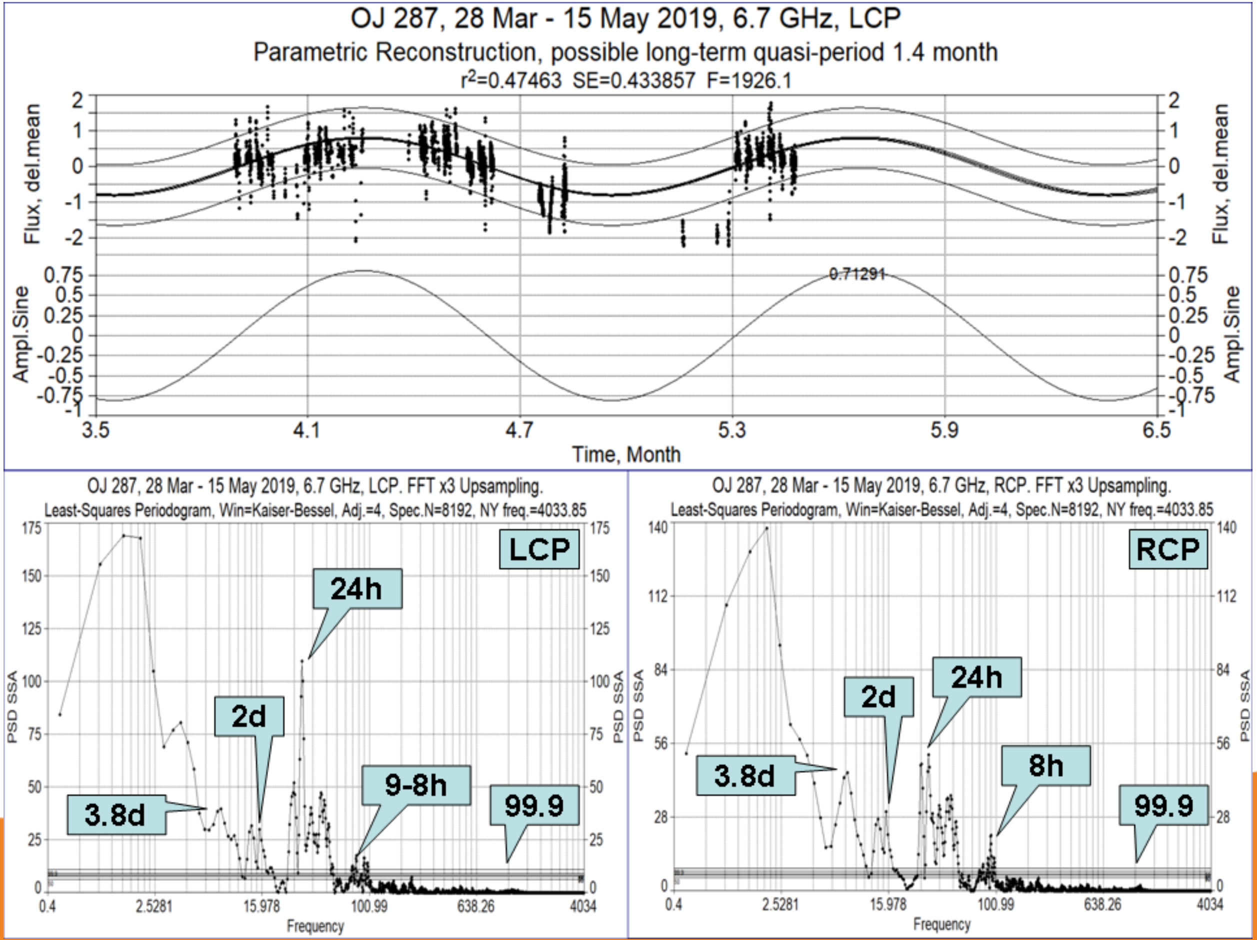
# Day-to-day variability of OJ 287 at frequency 6.7 GHz.




**At frequency 6.7 GHz, it is possible that long-term trend is observed, which is close to sinusoidal wave, with characteristic time about 1.4 months. On examples of periodograms, series of diurnal harmonics is visible. The longest quasiperiods are 15 and 3.8 days.**

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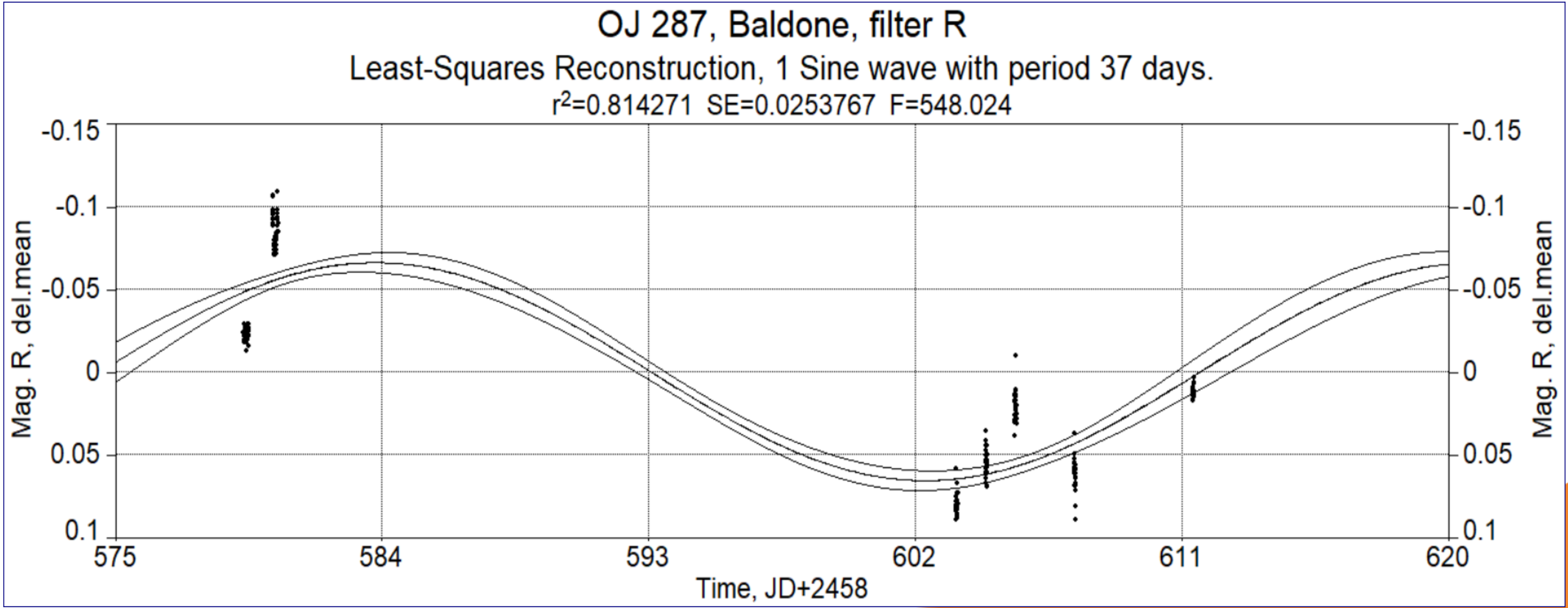
# OJ 287, observations at the Baldone Observatory (Latvia), filter R

**Subtracted average value 14.867 mag**




**Observations in Baldone, April 5 - May 7, 2019, best approximation by sinusoid with period 37 days.**

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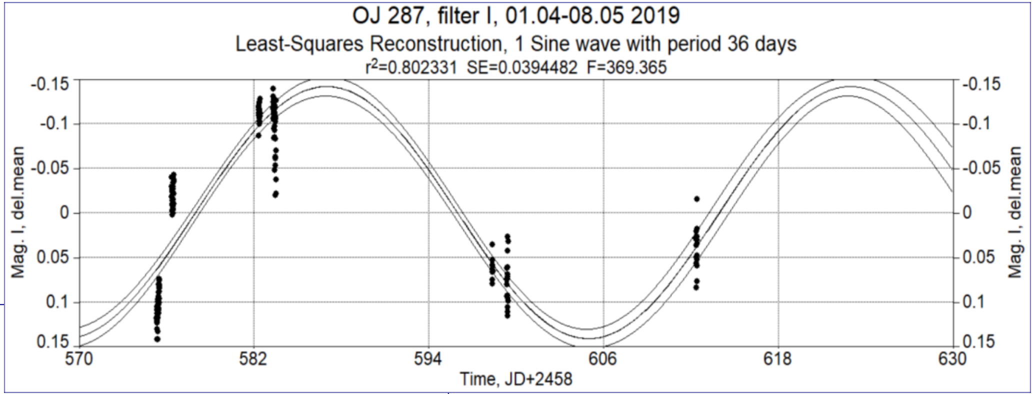
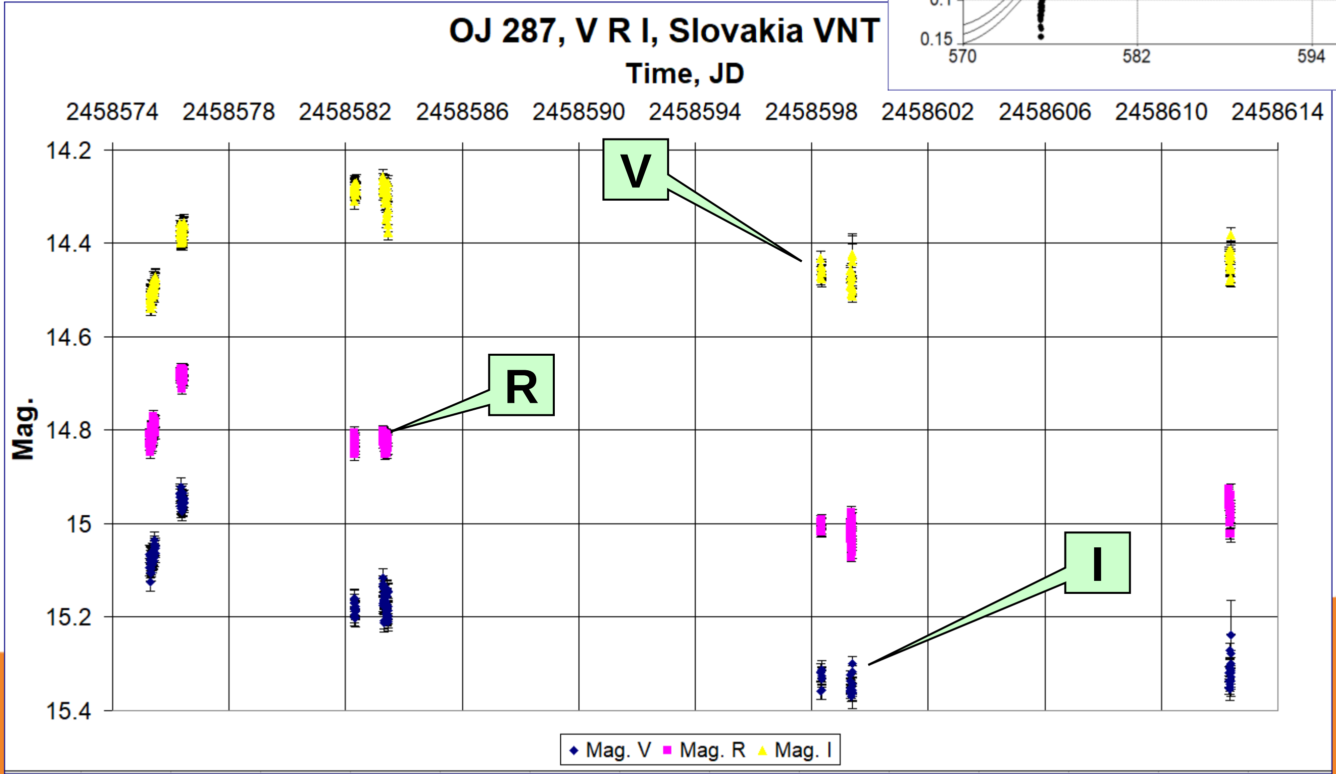
# OJ 287, observations of the Vihorlat Observatory (Slovakia), filters V, R, I




**Filter I, average 14.397 mag**

**Observations at the Vigorlat Observatory, April 1 - May 8, 2019, an example of approximation by one sinusoid for filter I, with period of 36 days.**

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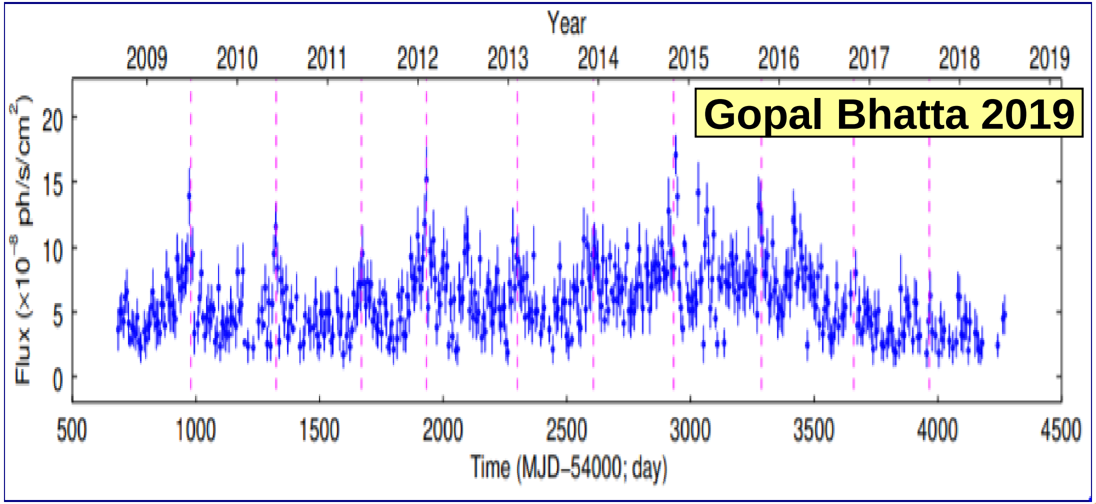
# MRK 501 BL-Lac object Intra-Day Variability probe

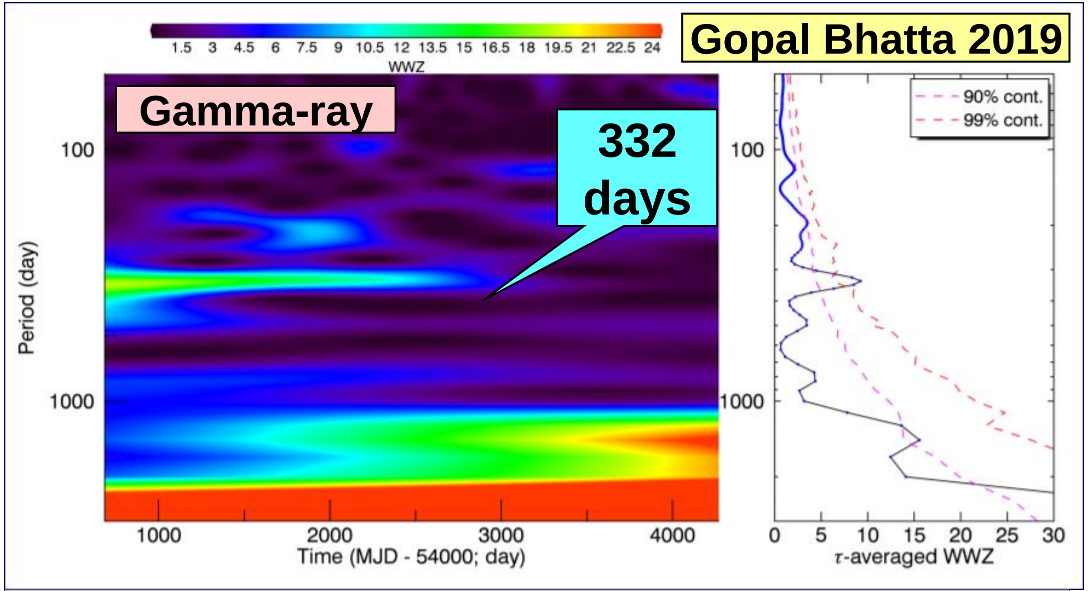
Image from Sloan Digital Sky Survey

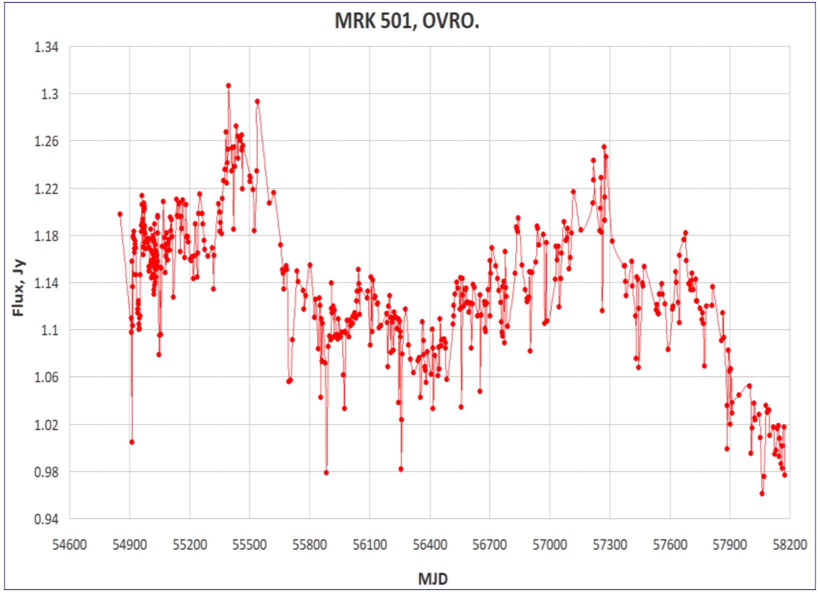
Markarian 501 active galaxy.

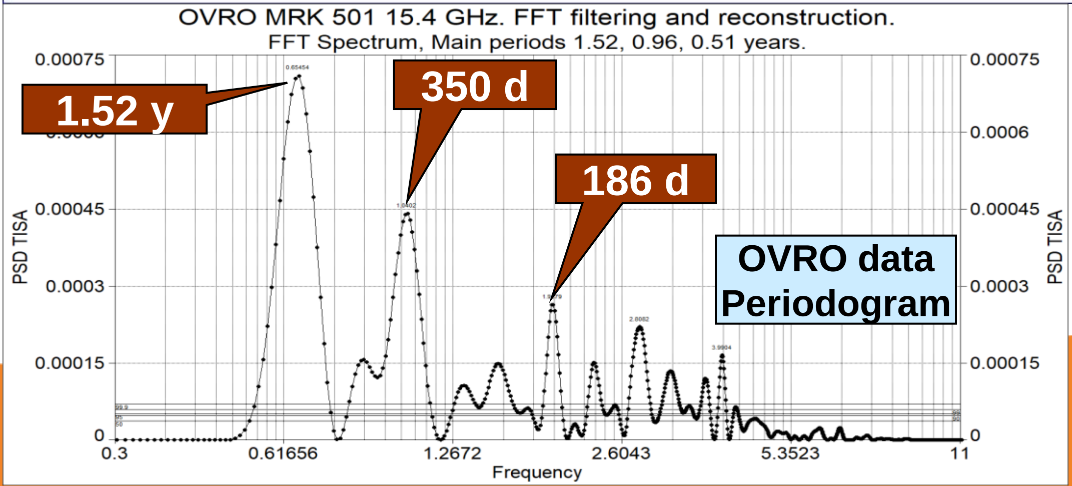
**MRK 501 - most powerful source above 0.1 TeV gamma ray energies.**




**Gopal Bhatta 2019, found strong quasiperiodic variations with decrease in amplitude of harmonic oscillation with time, in long-term light curve in gamma-range (Fermi/LAT data).**

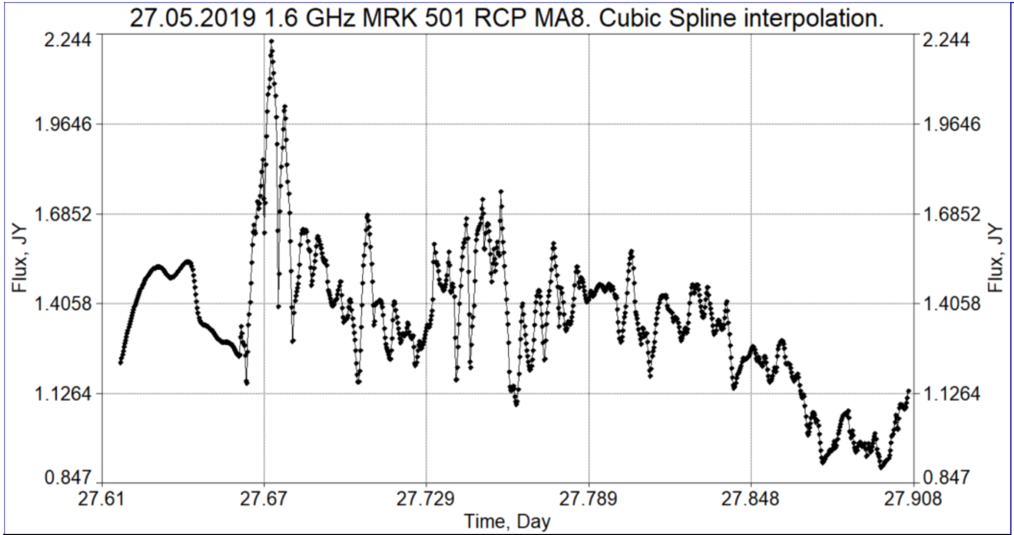


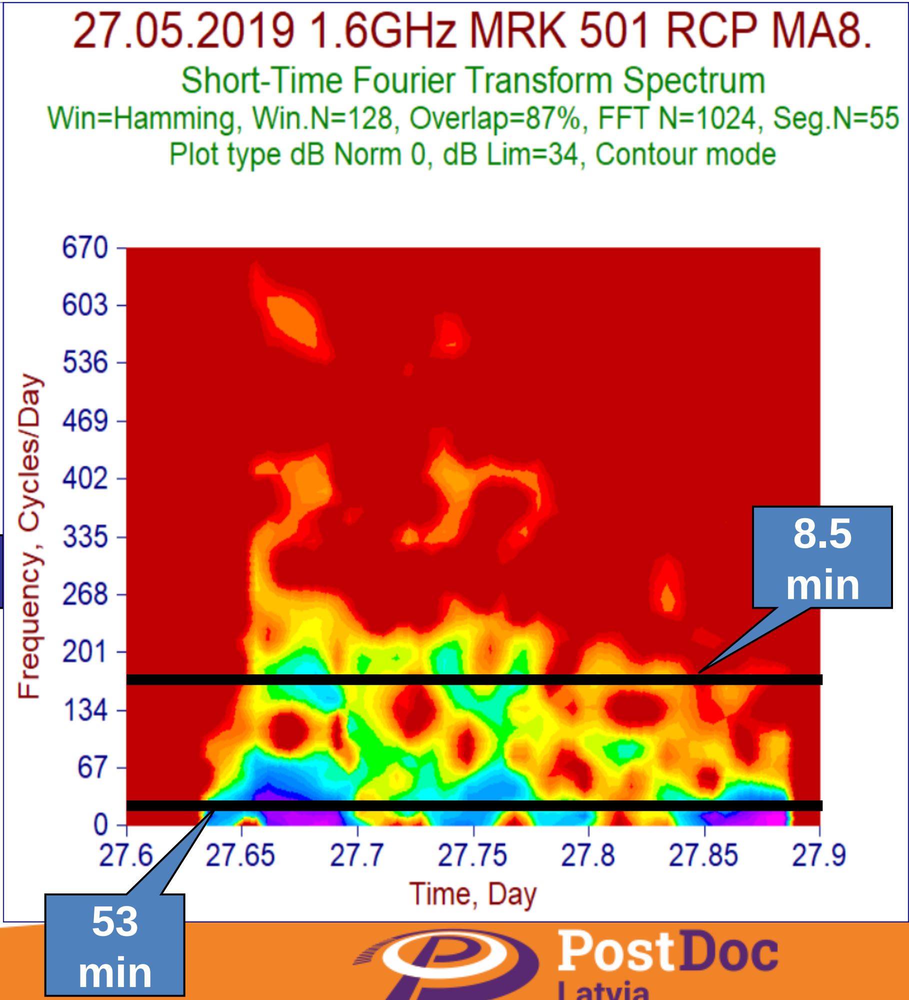

**40-m dish OVRO, 15 GHz obs. 2009-2018**

**Quasi period 332 days with used wavelet-transform was found in gamma range (Gopal Bhatta 2019), but quasiperiod with close value 350 days was obtained from OVRO radio observatory data at 15 GHz, after FFT filtration and subtracted long-term trend variations in flux density.**




# VIRAC, MRK 501, 1.6GHz, 27 May 2019, RCP

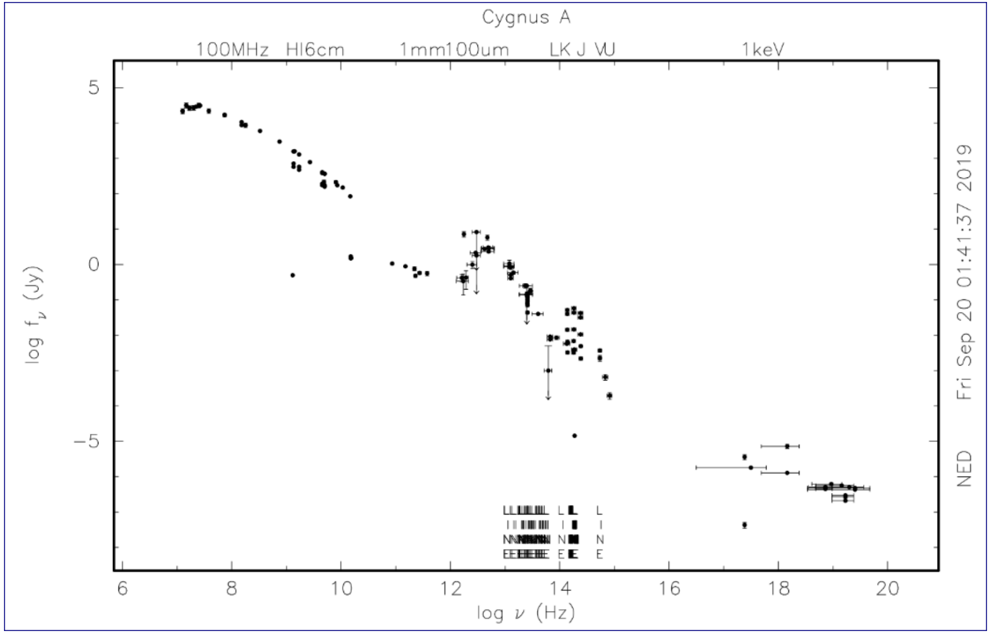
**According VIRAC data MRK 501, at frequency 1.6 GHz on different days values of quasiperiods from about 1 hour to several minutes are obtained. Since environmental effects appear significantly at 1.6 GHz, these flux variations are most likely external in nature. On right is example of spectrogram for flux recording in May 27, 2019.**



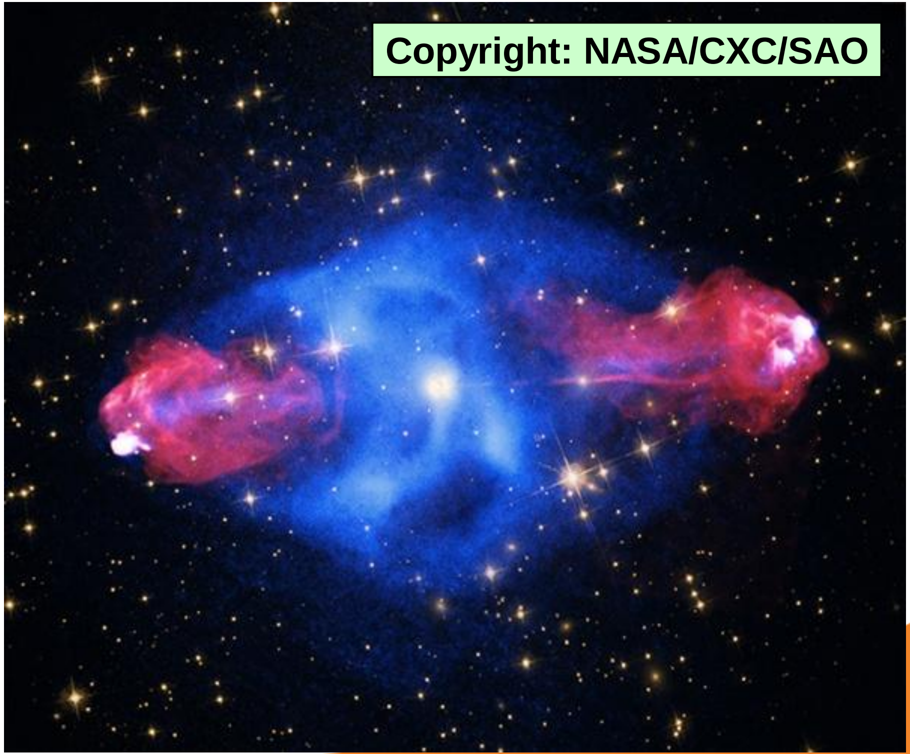

PostDoc Latvia

# "Cygnus A" classic FRII radio galaxy

Distance to "Cyg A" is 232 Mpc, and radio flux at 5 GHz is 373 Jy




Spectral Energy Distribution (SED) for Cyg A (NASA/IPAC EXTRAGALACTIC DATABASE)




Composite image shows "Cygnus A" in X-rays (blue), radio (red), and opitical light (yellow). Two jets from galaxy's supermassive black hole generate hotspots, which are located about 300.000 light-years from galaxy's center.

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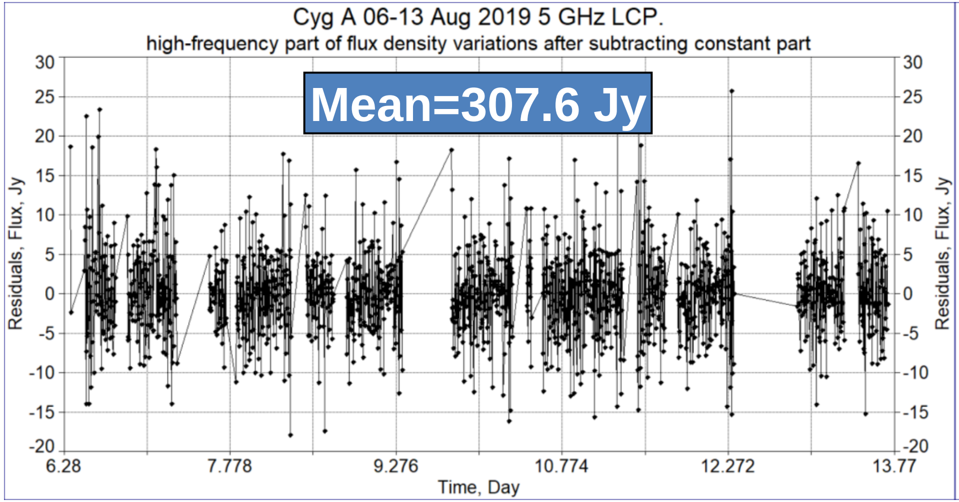
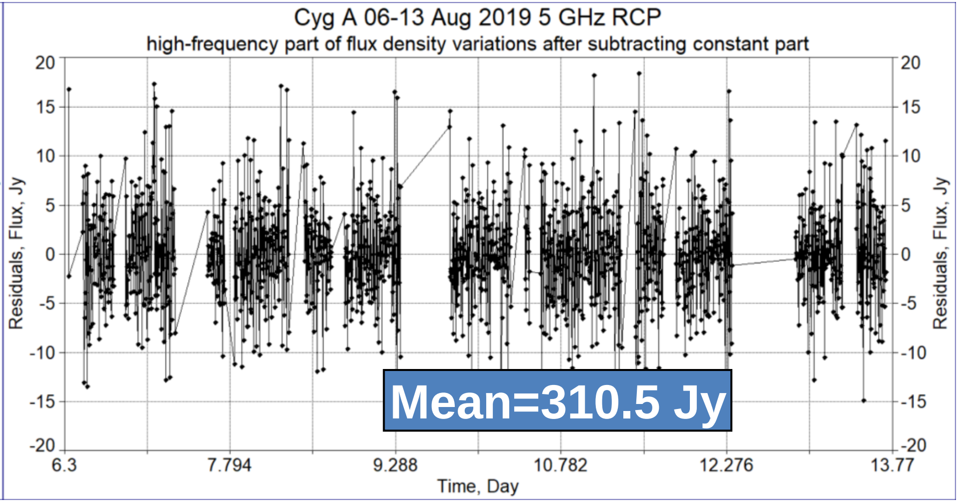
# VIRAC observations of “Cyg A” at 32-m dish, freq. 5 GHz




**The “Cygnus A” radio source is stable over long observation times, and it often used as calibration source (it can be seen from graphs at frequency 5 GHz after subtracting the constant part).**

**During observations, new observation technique was used, which allows obtaining up to 3 samples of flux density per second, but at cost of increasing noise level.**

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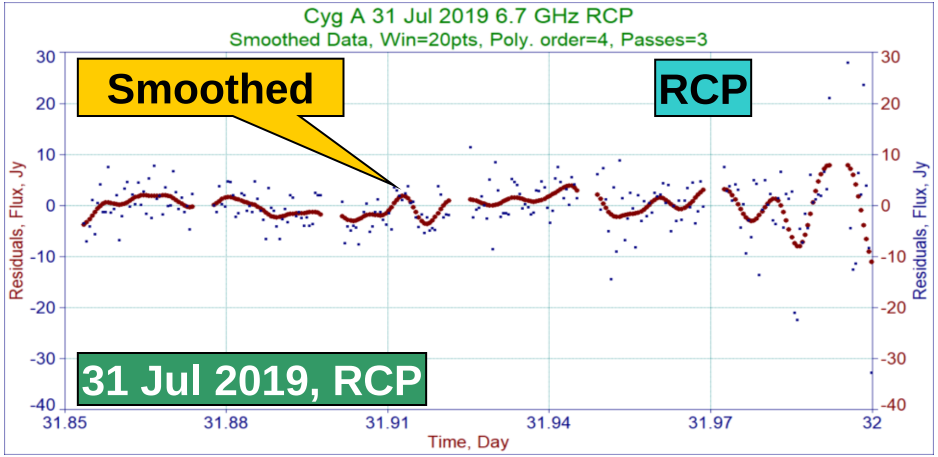
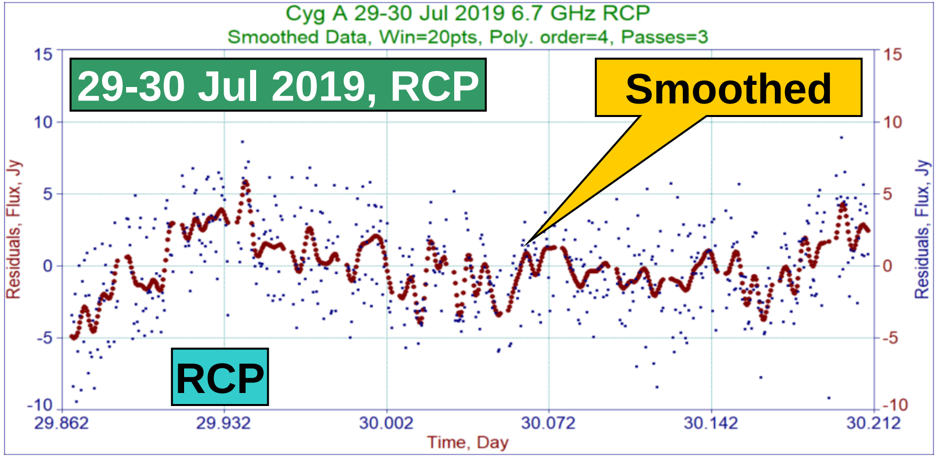
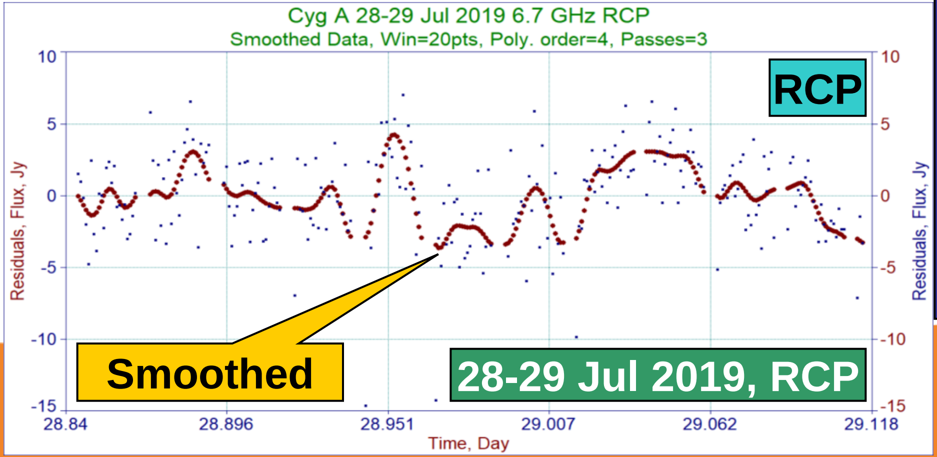
# VIRAC observations of “Cyg A” at 32-m dish, freq. 6.7 GHz




**From July 28 to July 31, 2019, small fast variations in flux density of “Cyg A” radio source were recorded. This requires additional verification. At frequencies 5 and 6.1 GHz it was not detected.**

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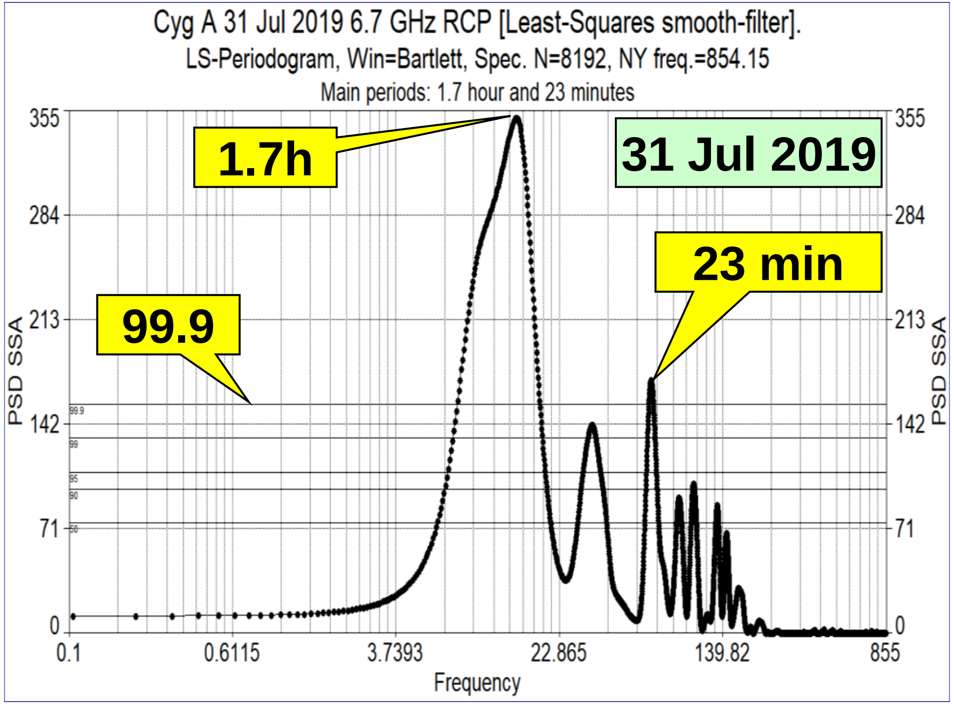
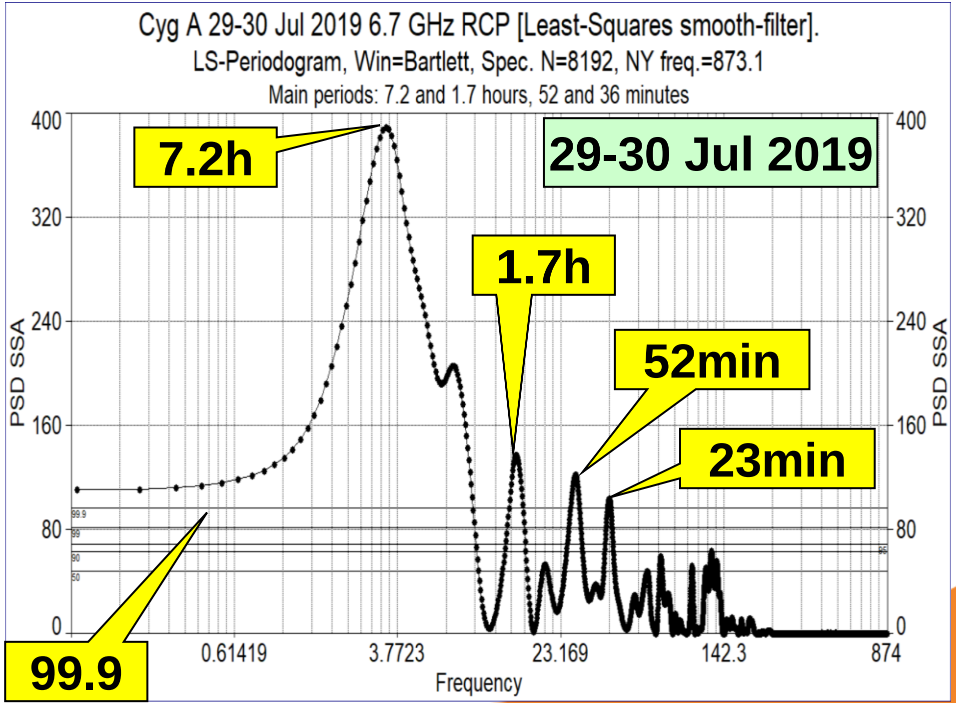
"Cyg A" examples of periodograms (for non-uniform time series) for observations on July 31 and 29-30, 2019, at 6.7 GHz, RCP. It can be seen that quasi-period about 1.7 hours is present for two days.




Thus, as previously assumed, "Cyg A" can have fast variability with characteristic time about several hours (with good long-term stability) which appears only on certain days. Perhaps this is "external" variability associated with environment. Further thorough verification is required.

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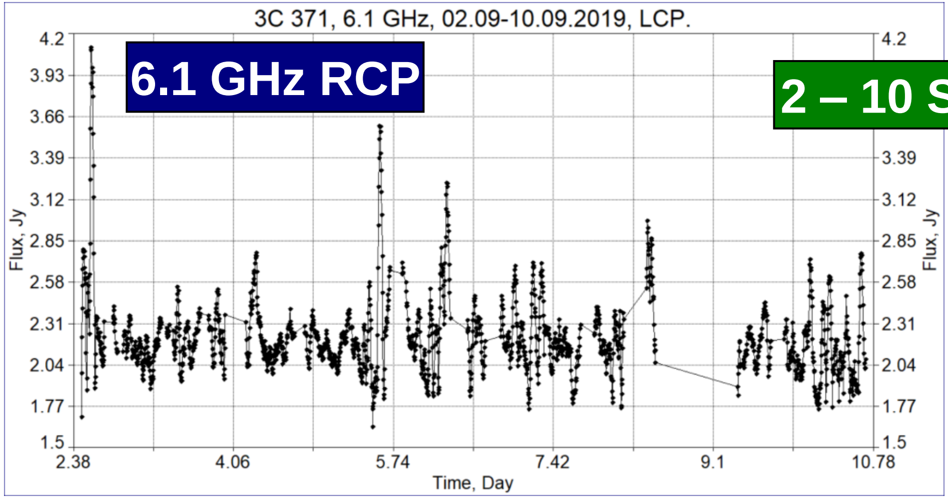
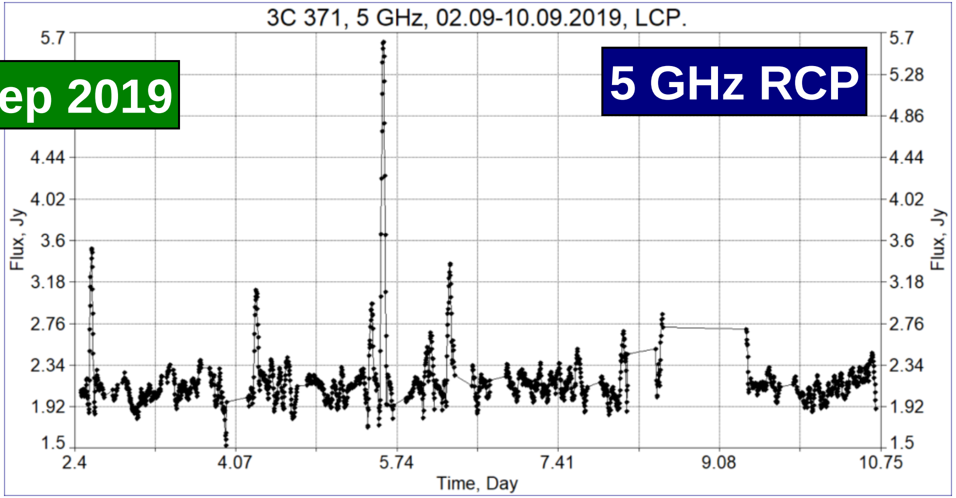
# 3C 371 BL-Lac object VIRAC observations at 5 and 6.1 GHz

**6.1 GHz RCP**

**2 – 10 Sep 2019**

**5 GHz RCP**

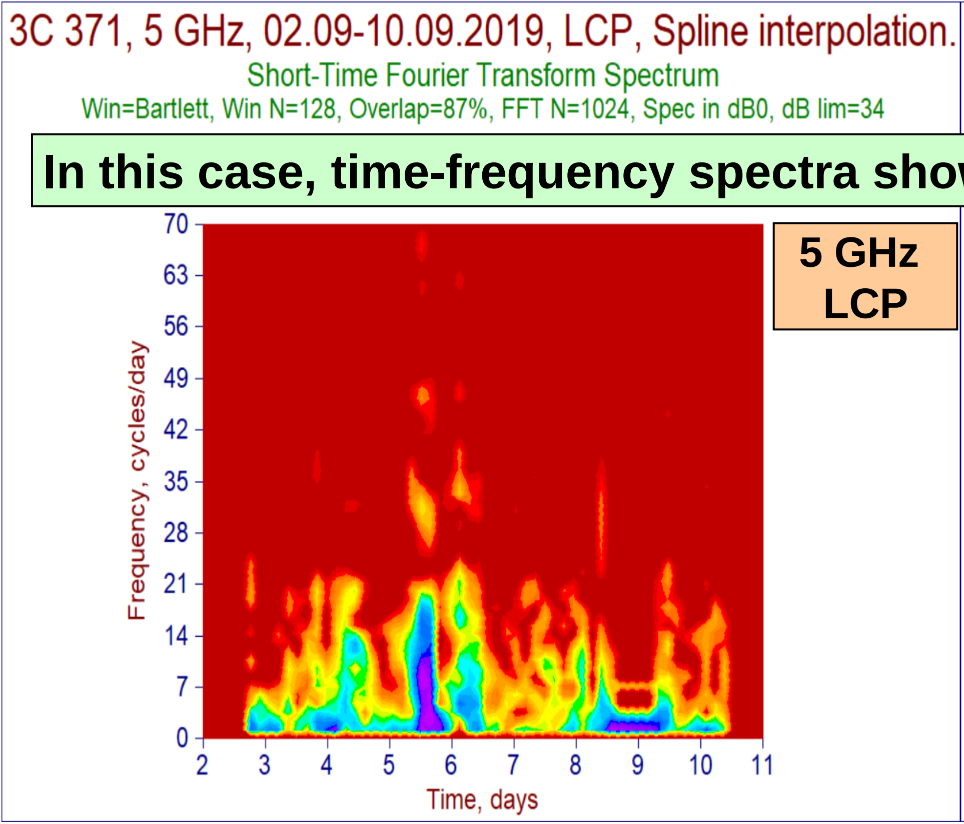


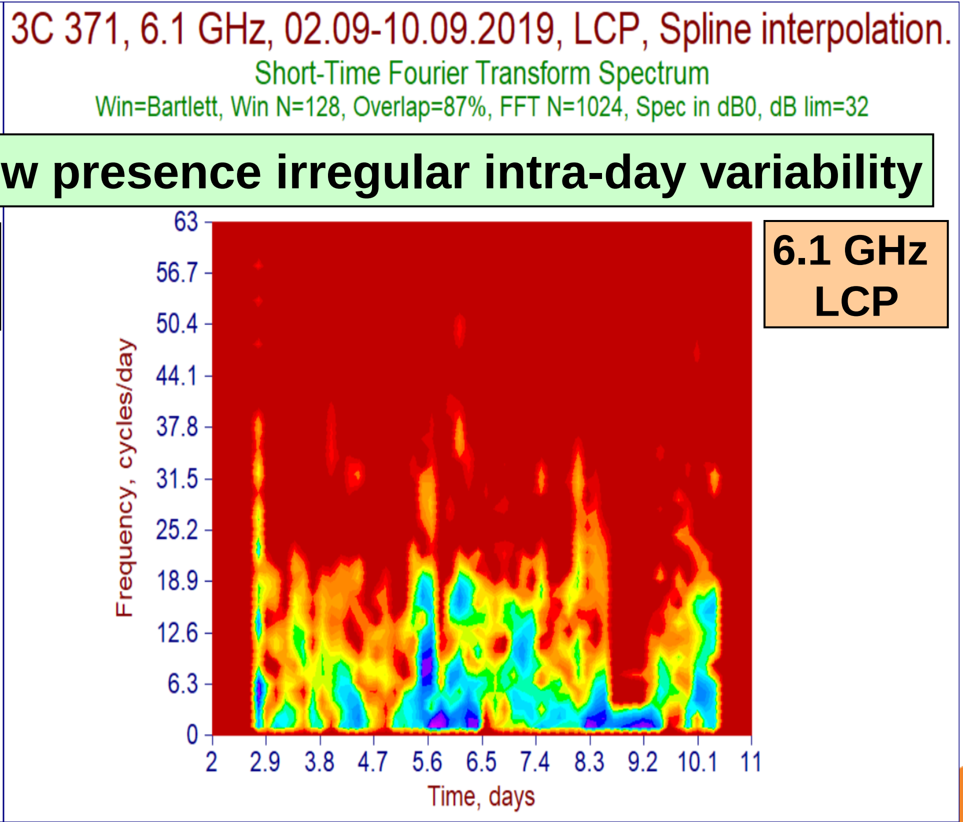




**Example of smoothed observational data for radio source 3C 371 at frequencies 5 and 6.1 GHz (left circular polarization) during September 2-10, 2019.**

**In September 2019, program for joint observation of 3C 371 BL-Lac object in radio (VIRAC, Latvia) and optical *(Odessa National University observatory, Ukraine; Baldone, Latvia; Vihorlat, Slovakia)* bands was launched. This radio source is in Draco constellation and very convenient for almost continuous observations.**

**Mean flux: 2.25 Jy (RCP), 2.20 Jy (LCP) at 5 GHz and 2.10 (RCP), 2.23 Jy (LCP) at 6.1 GHz.**



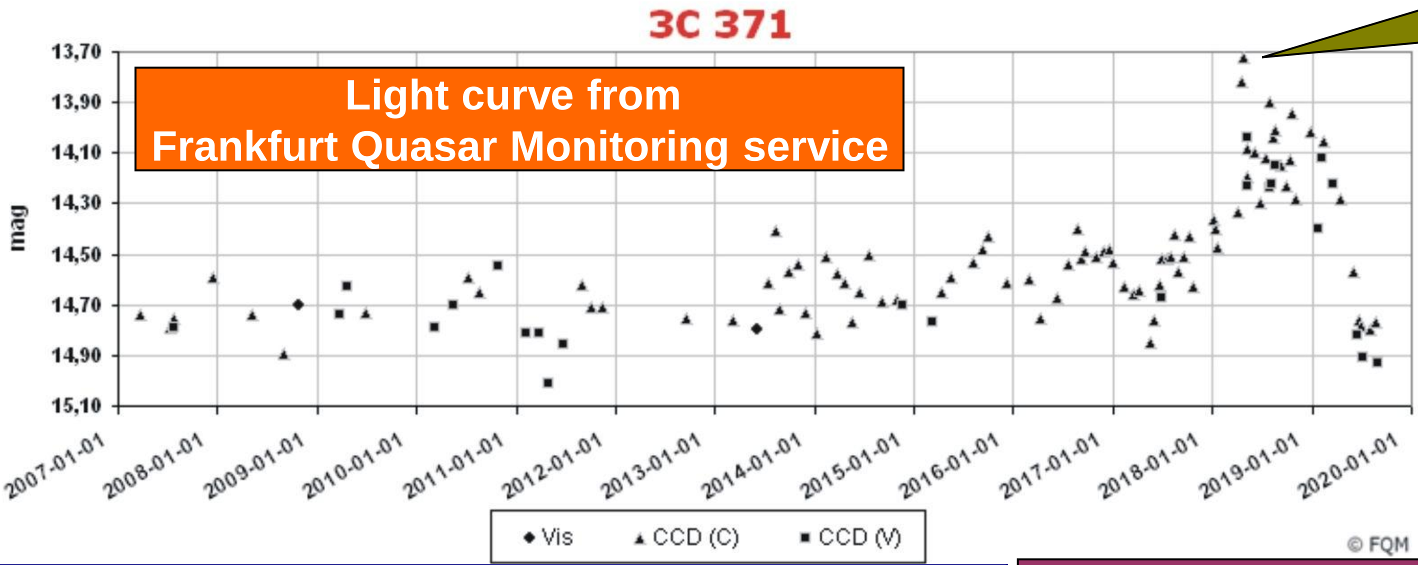

**In this case, time-frequency spectra show presence irregular intra-day variability**

**Short-Time-FFT spectra show that in observation session at September 2–10 there were only irregular (nonharmonic) variations in flux density, with characteristic time 14.6, 2.6 hours (5 GHz) and 12.3, 2.3 hours (6.1 GHz).**

PostDoc Latvia

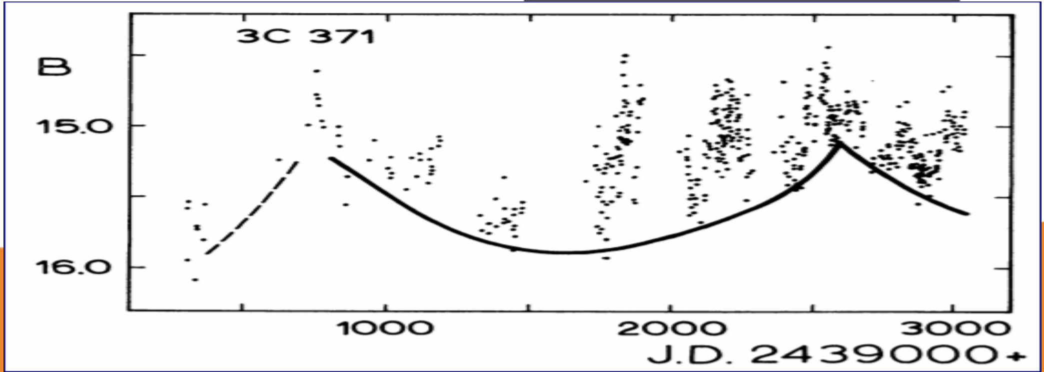
# 3C 371 BL-Lac object, optical variability

Optical flare at beginning 2019




Light curve from
Frankfurt Quasar Monitoring service

IDV of 3C 371 in optical range is considered in detail at *Michael T. Carini, John C. Noble 1998* and has since been repeatedly confirmed.

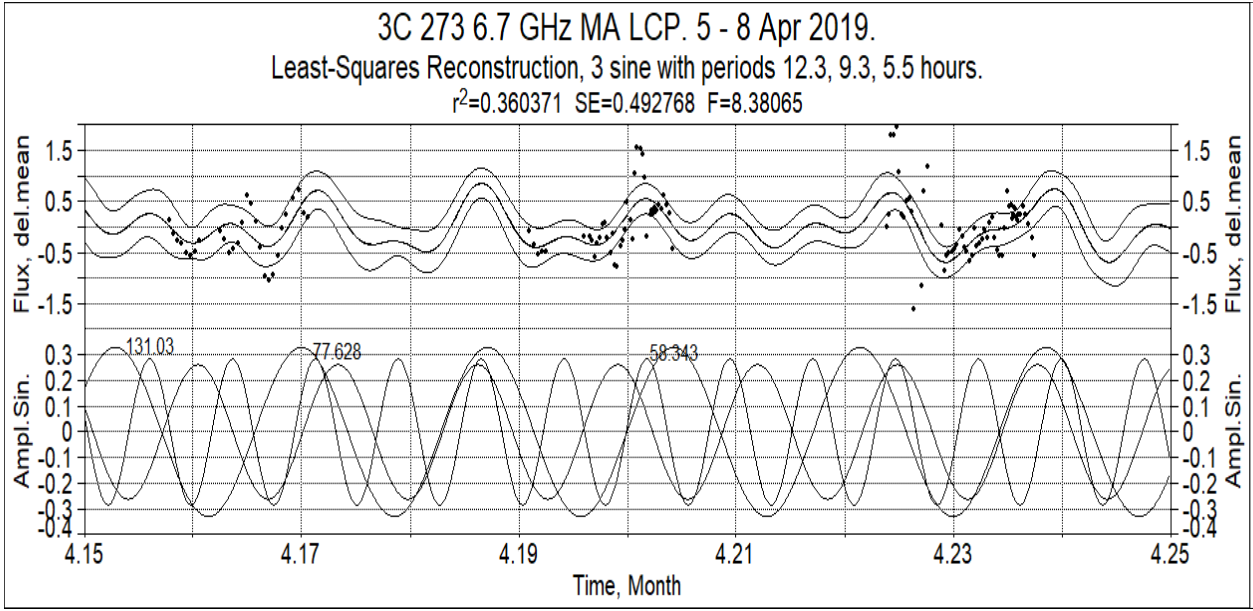


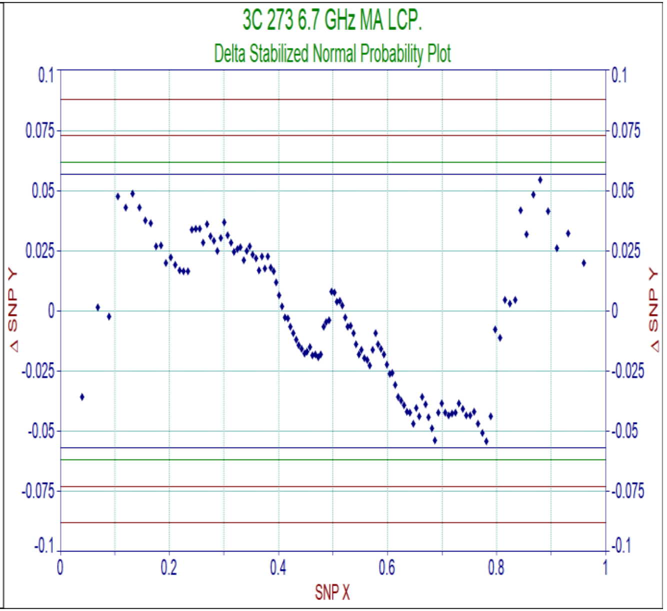

Long-term light curve of 3C 371 (1966 - 1973) in B filter, showed flare-like variability (this is typical for BL-Lac objects). Picture from article *M.K. Babadzanjanz, E.T. Belokon 1975.*

Latvia

# 3C 273, VIRAC observations at 6.7 GHz

**5 – 8 Apr 2019, 6.7 GHz, LCP**




**Approximation of smoothed data (April 5 - 8) with three sinusoids, periods of 12.3, 9.3, 5.5 hours. Plot of stabilized normal probability for residuals (on right) shows normal distribution of residuals (line inside confidence intervals).**

PostDoc Latvia

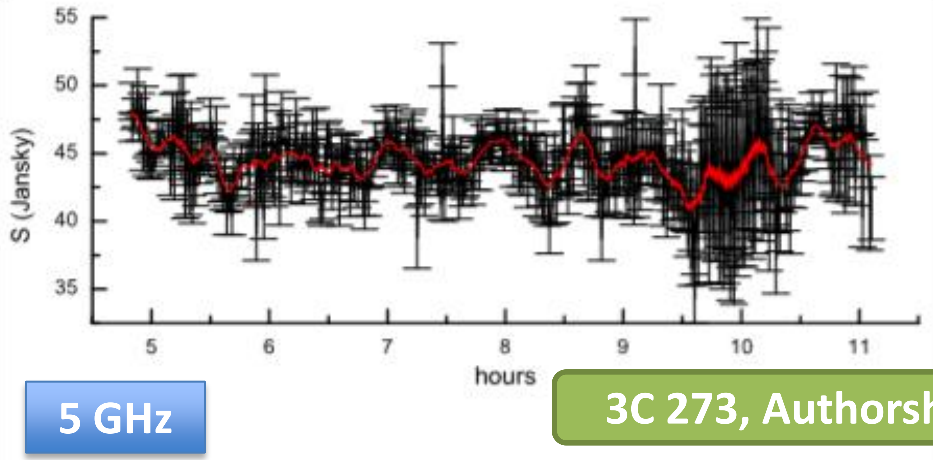


Fig. 1 6 cm light curve of 3c273 on day Sep. 18, 2000

3C 273, Authorship, Xiang Liu 2003

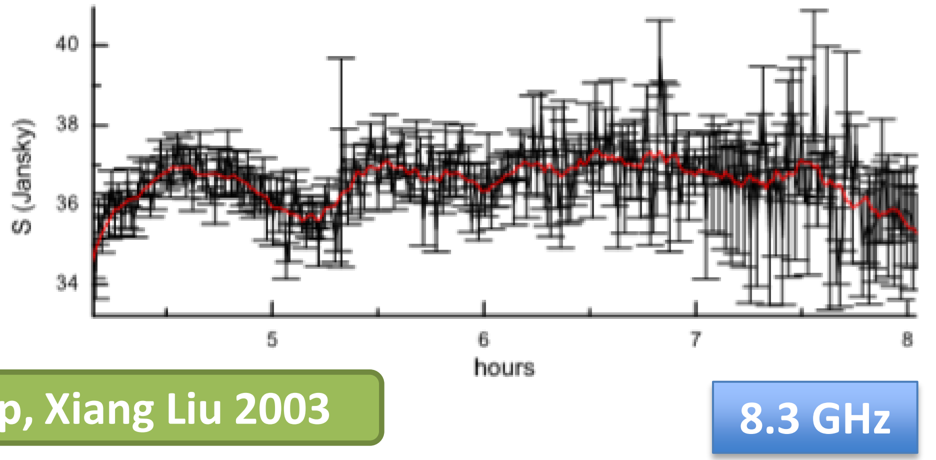
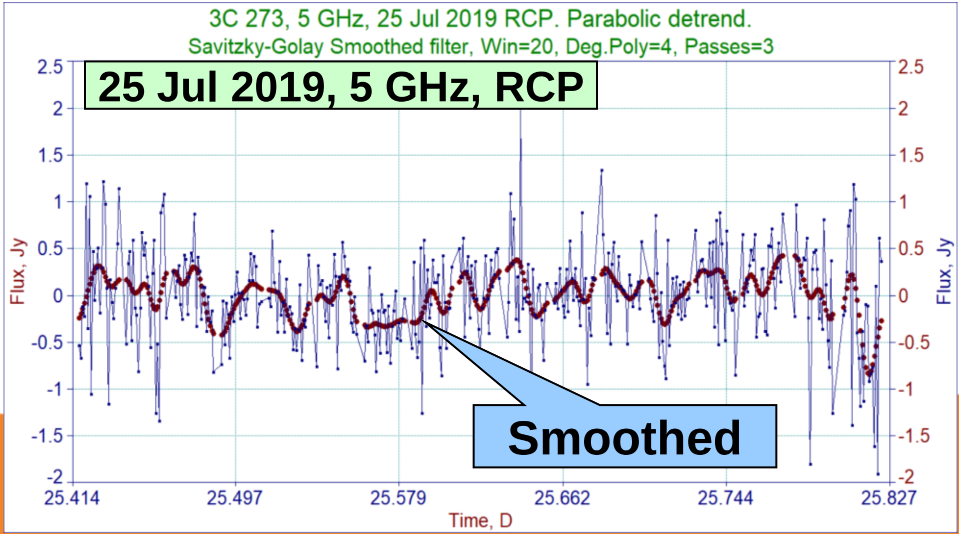


Fig. 2 3.6 cm light curve of 3c273 on day Oct. 24, 2000

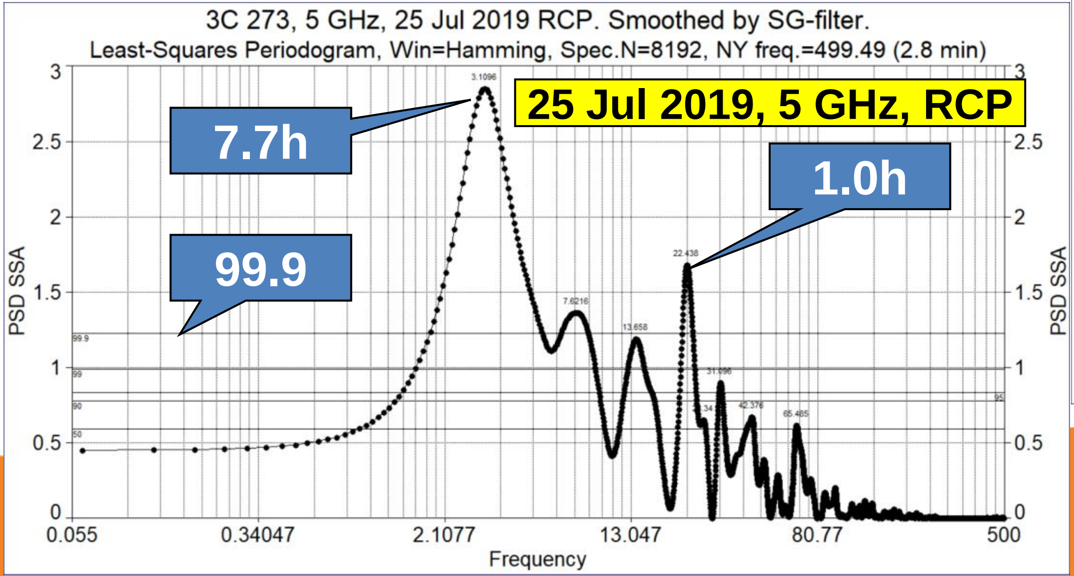


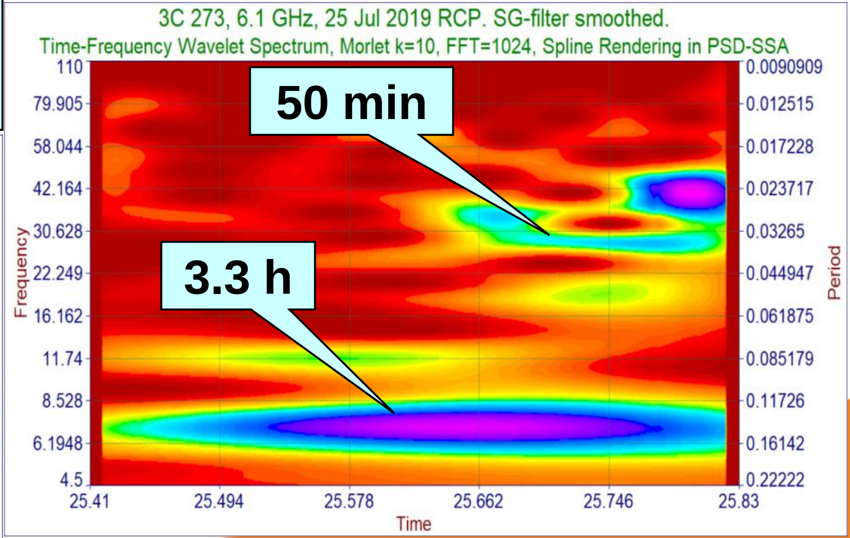

**Chinese observations showed presence of extremely fast 3C 273 variability with characteristic time about 1 hour.** In August 2019, there was attempt to repeat similar observations made at 25-m telescope in Urumqi Radio Observatory (China) at the 32-m VIRAC, Latvia, radio telescope, at frequencies 5 and 6.1 GHz.

Latvia

**In July 2019, there were problems giving parabolic trends in observations. However, for testing purposes, estimate of presence Intra-Day Variability indicates rapid flux variations on July 25 with main period ≈ 1 hour (at 5 and 6.1 Ghz). This is close to result obtained by Xiang Liu 2003 also at 5 GHz. Only on this day (in July session) is quasiperiodic IDV recorded. 7.7 hours quasiperiod is close to 8 hours of daily 24-h harmonic.**

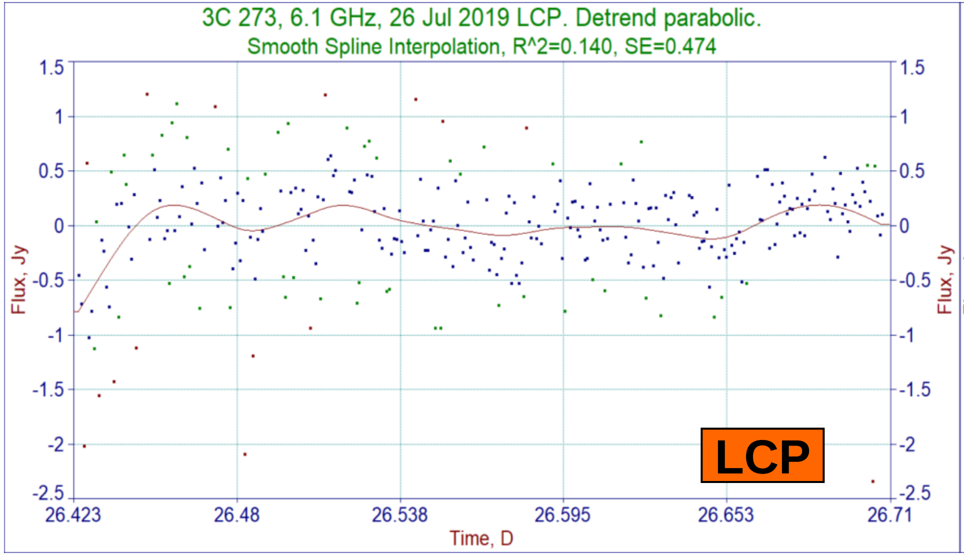
**99.9 confidence level shows that only in 1 out of 1000 case random noise can give maxima above this level.**

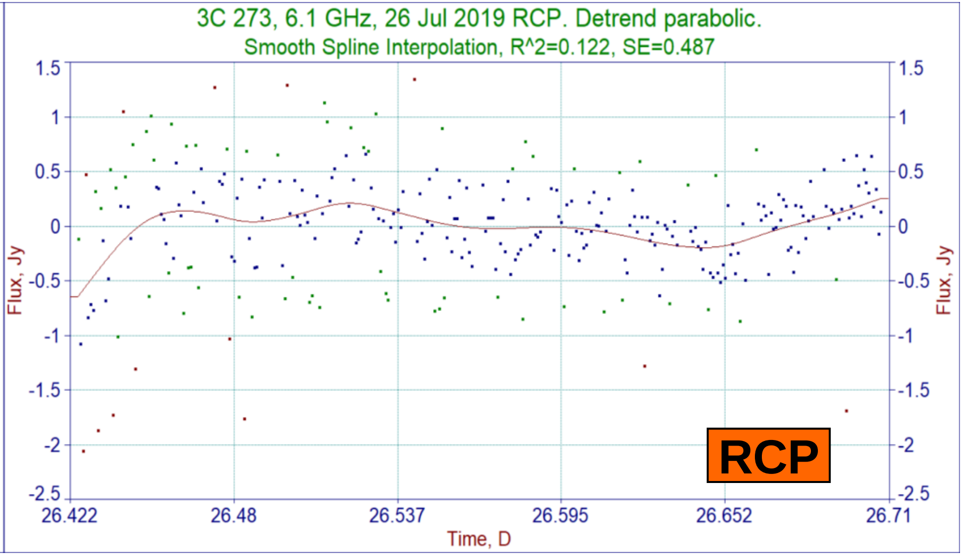



**25 Jul 2019, 6.1 GHz, RCP**

# Example July 26, 6.1 GHz, when quasi-harmonic appearance of IDV was not presented in quasar 3C 273.




**Cubic smooth spline (deBoor's SMOOTH (P. 235-243), P.Craven, G.Wahba 1979) is good IDV detector in radio flux, with significant red noise, as can be seen in example shown, spline shows practically no rapid variations, only slow, trendy variations with low amplitude.**

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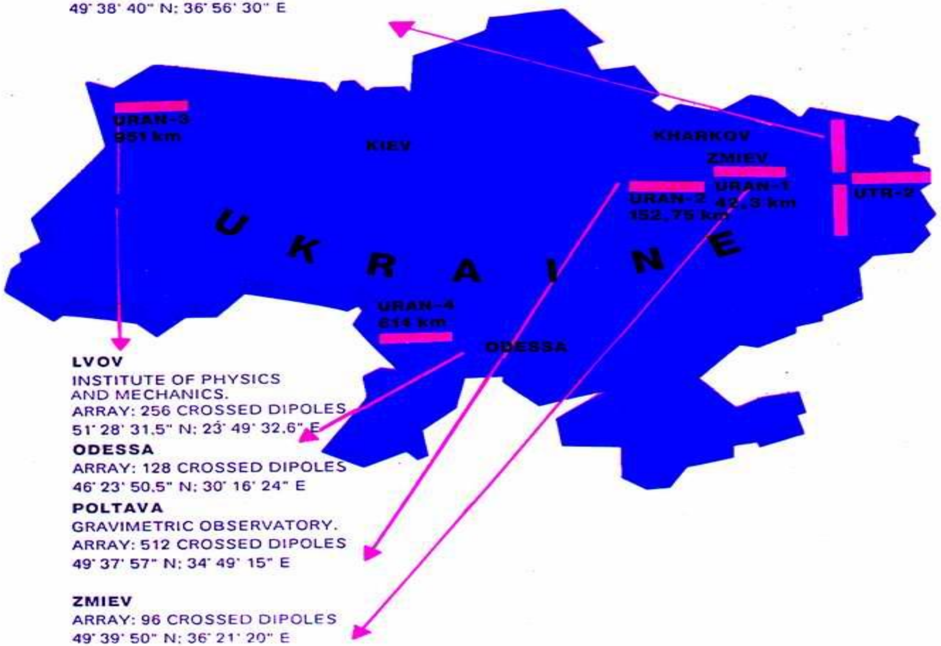
# The results of more 30-th years monitoring of fluxes of powerful space radio sources at RT "URAN-4" of the Odessa Observatory RI NASU and space weather.

# UKRAINIAN RADIO INTERFEROMETER
## OF THE ACADEMY OF SCIENCES /URAN/

**KHARKOV**

INSTITUTE OF RADIO ASTRONOMY OF THE ACADEMY OF SCIENCES OF THE UKRAINE
4, KRASNOZNAMENNAYA STR.,KHARKOV, 310002, UKRAINE

**GRAKOVO**
ARRAY: 2040 HORIZONTAL DIPOLES
49° 38' 40" N; 36° 56' 30" E




**LVOV**
INSTITUTE OF PHYSICS
AND MECHANICS.
ARRAY: 256 CROSSED DIPOLES
51° 28' 31,5" N; 23° 49' 32,6" E

**ODESSA**
ARRAY: 128 CROSSED DIPOLES
46° 23' 50,5" N; 30° 16' 24" E

**POLTAVA**
GRAVIMETRIC OBSERVATORY.
ARRAY: 512 CROSSED DIPOLES
49° 37' 57" N; 34° 49' 15" E

**ZMIEV**
ARRAY: 96 CROSSED DIPOLES
49° 39' 50" N; 36° 21' 20" E

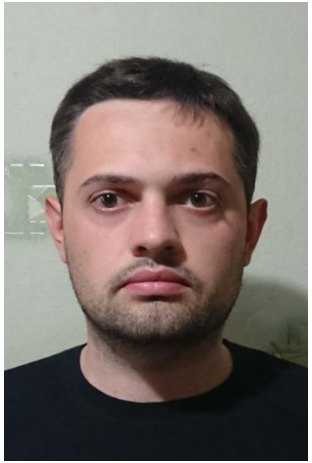
# Radio-telescope URAN-4 (Odessa, Ukraine)

# Our research team in Radio-astronomical Institute and cooperation

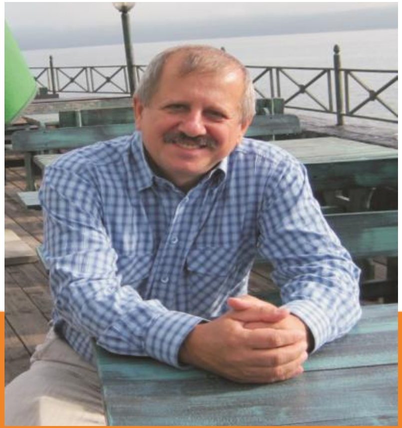
**Head – Dr. Michail Ryabov**

**Dr. Artem Sukharev**

**Luba Sobitniak, Junior Staff Scientist**



**Vladimir Komendant, leading engineer-radiophysicist**



**Cooperation – Prof. M.I. Orlyuk Head Department Geomagnetic Variations Geophysics Institute NAS of Ukraine**

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## Program of monitoring

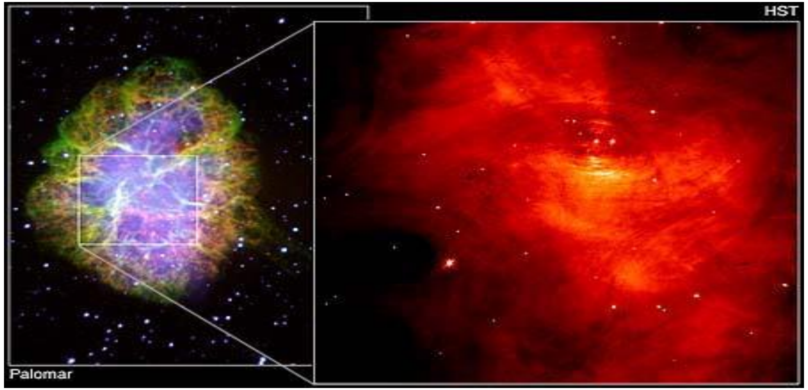
**3C144** $\alpha = 05^h\ 31^m\ 30^s$ $\delta = 21^\circ\ 39^m$

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

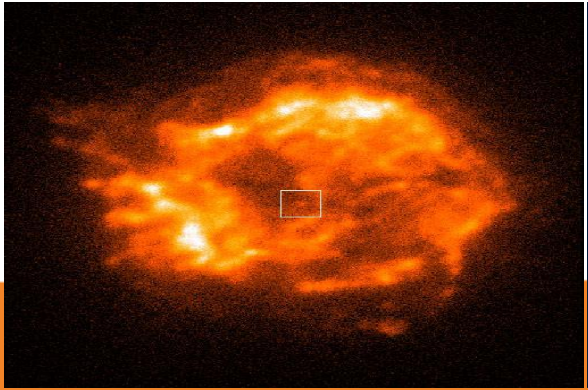
## 3C144 (Crab Nebula – SNR)

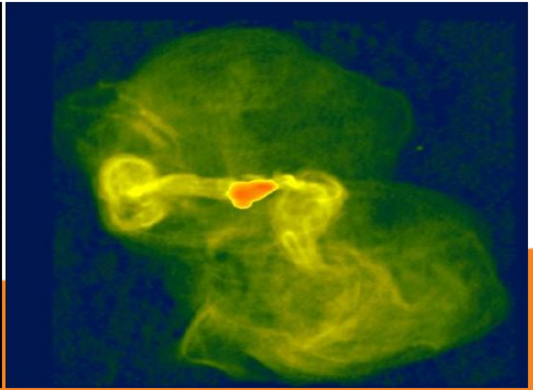


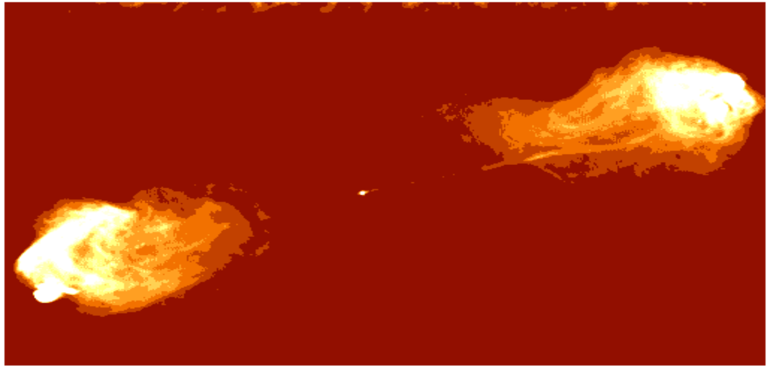

## 3C 274 – VirgoA- Radiogalaxy

## 3C 405-CygA-Radiogalaxy

## 3C 461 – CasA - SNR







Latvia

## Observations of sources within days

**3C144**

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

**3C274**

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

**3C405**

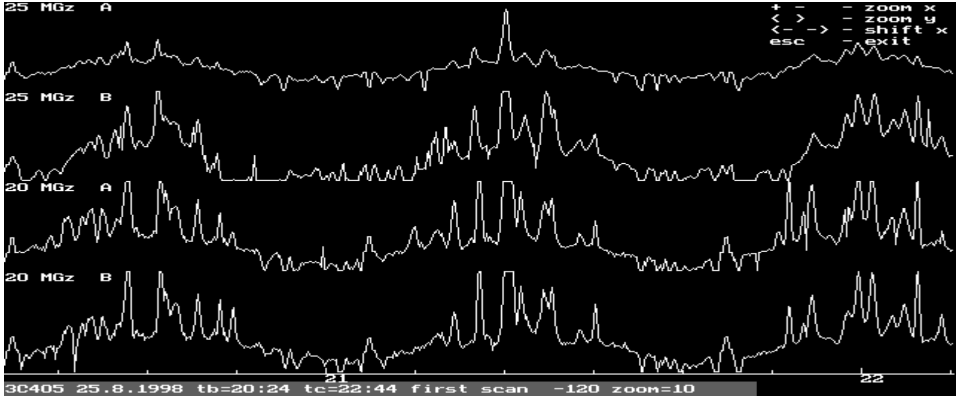
**- 120m до + 80 m , ΔT = 40m , 6 scans.**

**3C461**

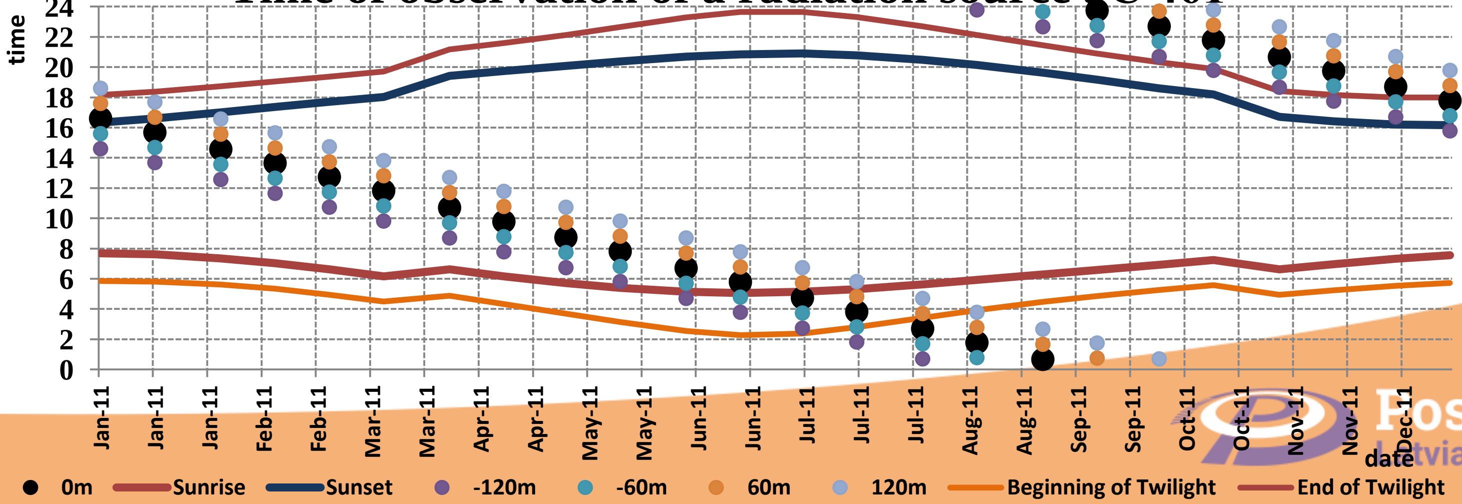
**- 60 m до + 120 m , ΔT = 60m , 4 scans**

**only per day - 13 hours 20 minutes.**

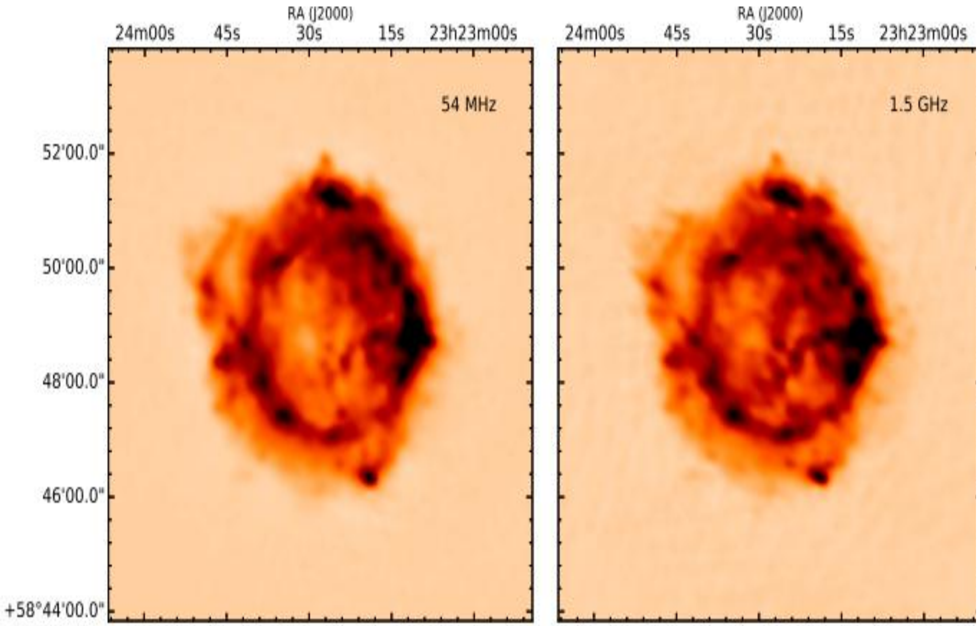
## Example of record radio source 3C405 received in the automatic mode "URAN-4" phased array

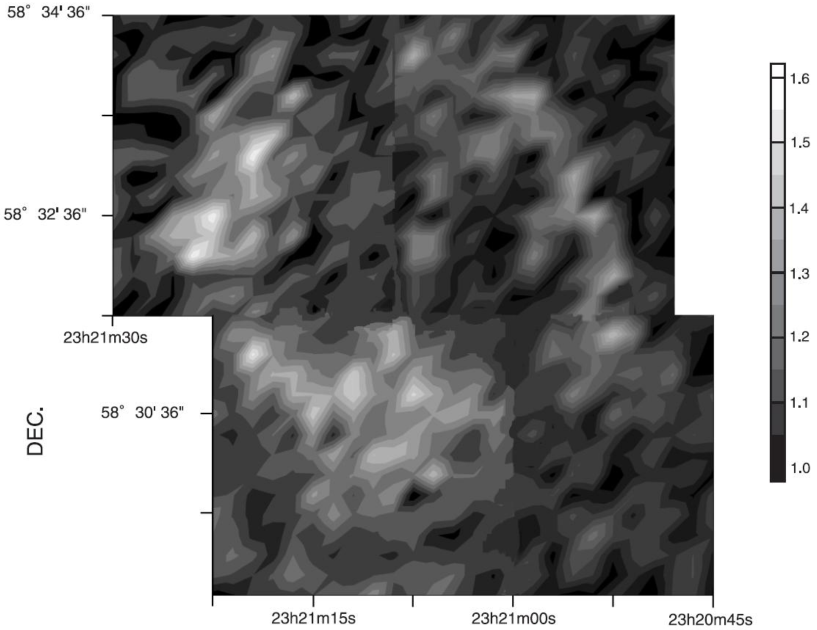



## Time of observation of a radiation source 3C 461



# Super nova remnant Cas A (3C461)

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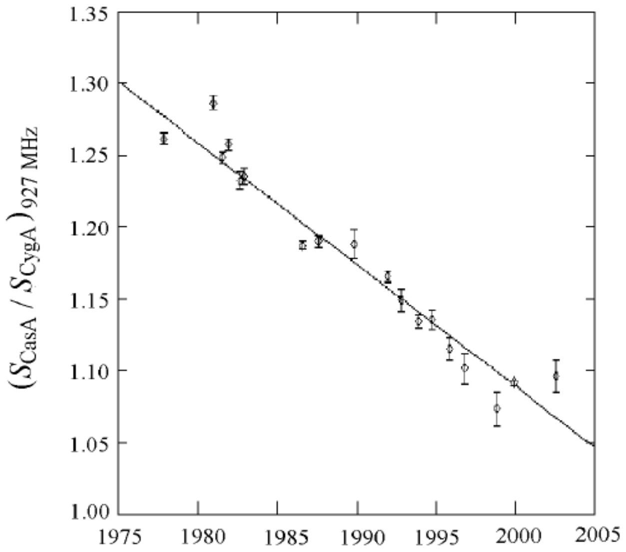
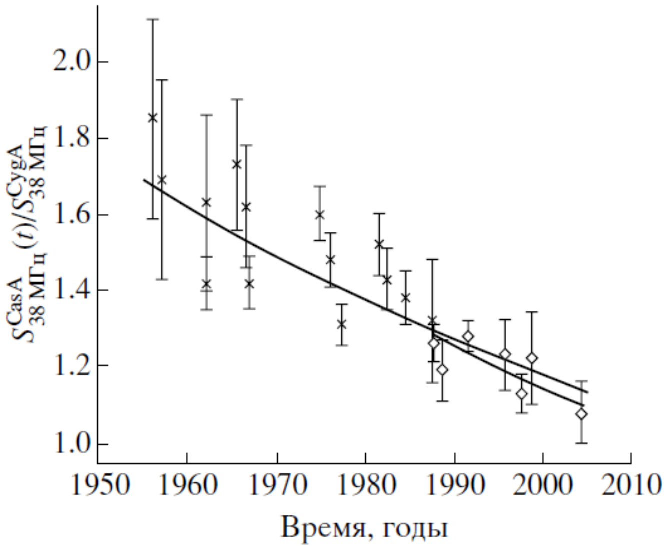
# Secular decrease flux Cas A (927 MHz and 38 MHz)

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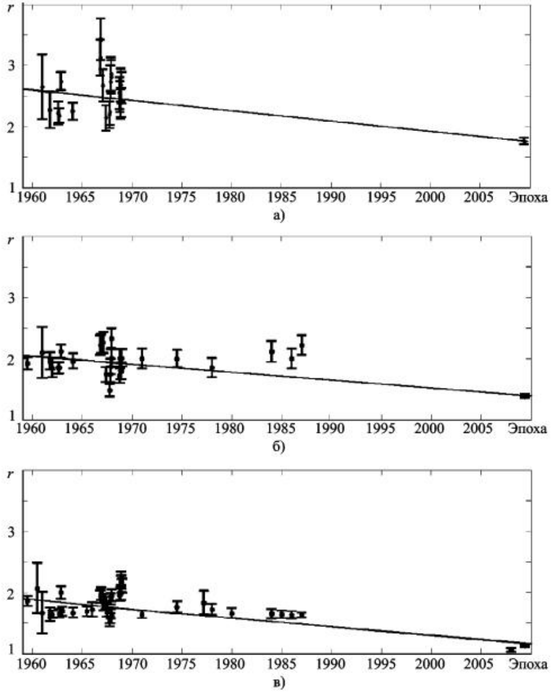
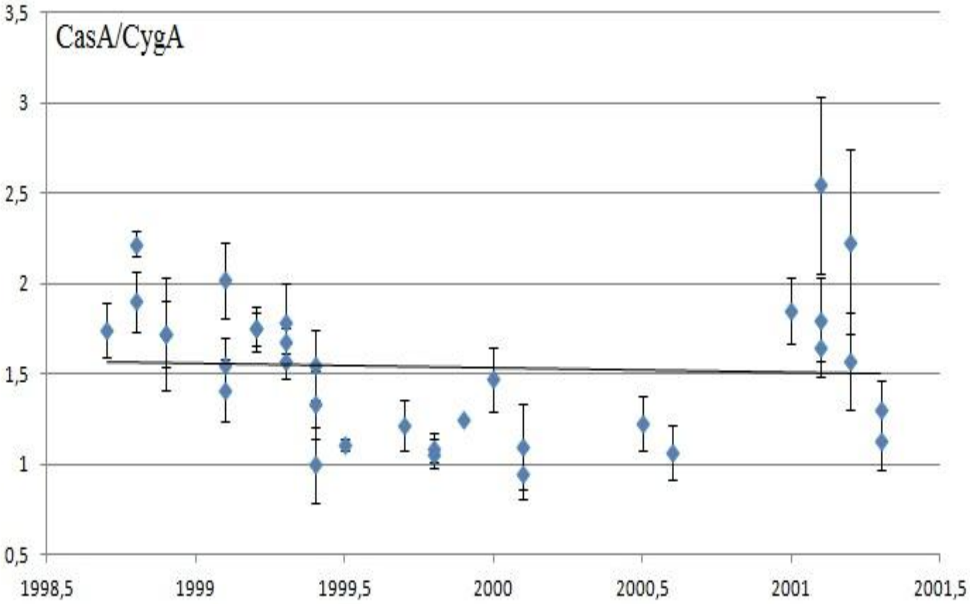
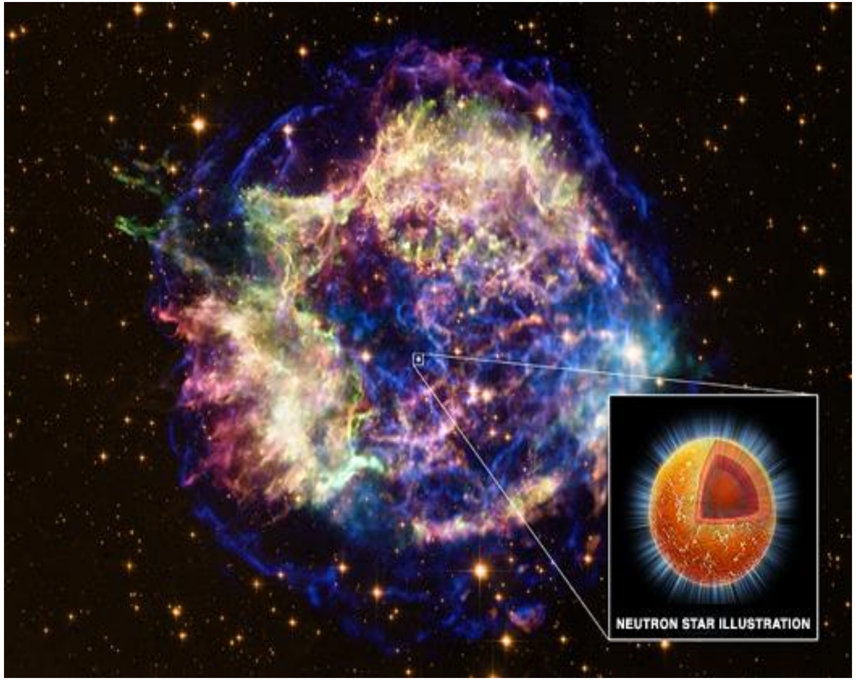
# Secular decrease  flux Cas A (25 MHz and 20 MHz)



$d_\nu[\%years^{-1}] = -(0.63\pm0.02)+(0.04\pm0.01)\ln\nu[GHz]+(1.51\pm0.16)x10^{-5}(\nu[GHz])^{-2.1}$




- $d_{(81MHz)}$ = -0.71 ± 0.06 % год$^{-1}$ (1949–2008.9)
- $d_{(151MHz)}$ = -0.78 ± 0.04% год$^{-1}$
- ( 1966.5–2006.6)
- $d_{(290MHz)}$ = -0.61 ± 0.03% год$^{-1}$ (1978.8–2011.7)

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# Space weather and its influence on an atmosphere of the Earth in a north-west part of Black Sea.

- The upper ionized layer of the Earth's atmosphere - ionosphere responds most sensitatively to the state of space.
- The ionosphere is "conductor" and active participant of all space and geophysical effects on biological systems.
- Radiotelescope “URAN-4” is located in a zone of magnetic anomaly.
- This zone promotes formation of the raised reaction to change conditions of space weather.

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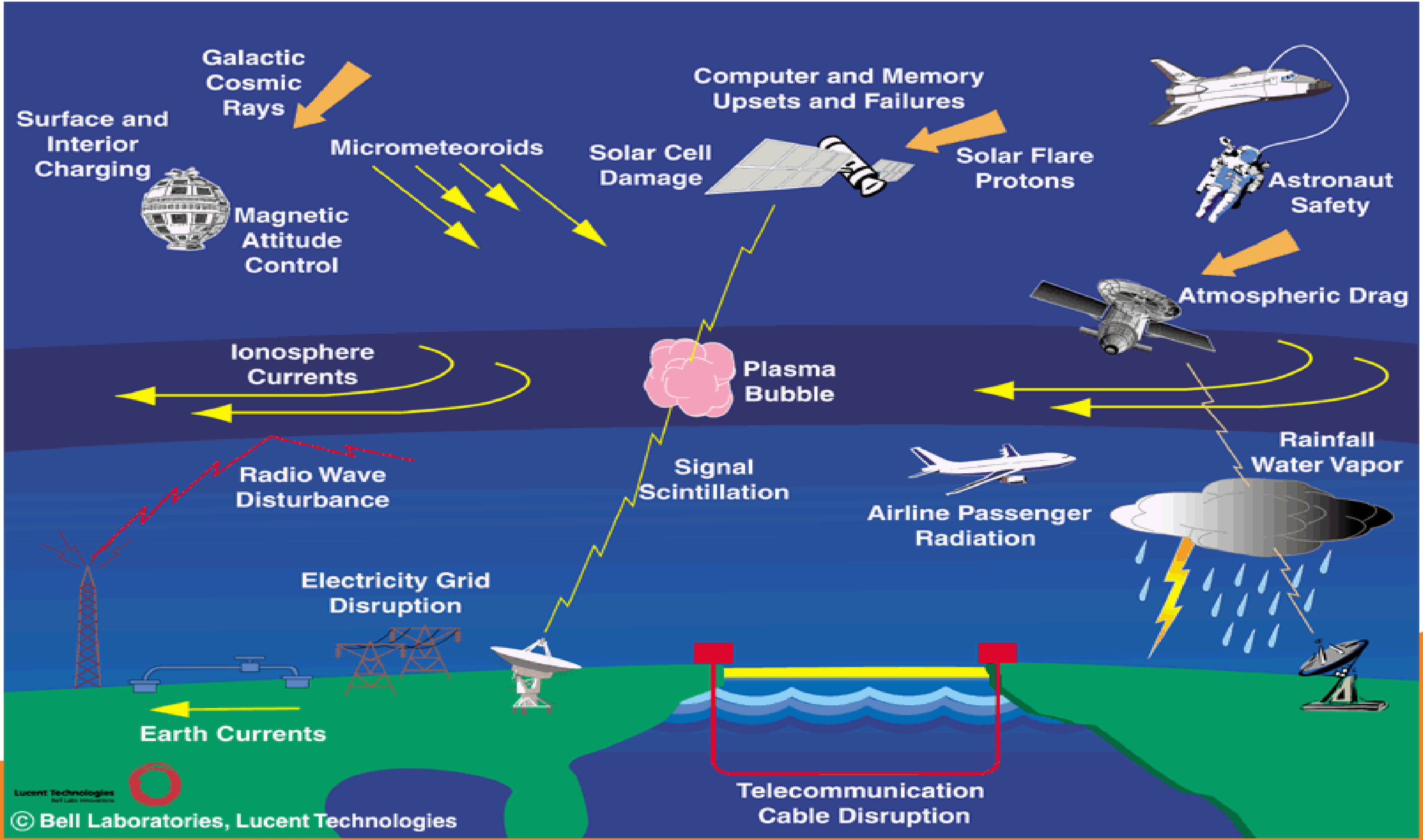
# Space weather on the Earth – what is it ?

- 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- Magnetosphere- Ionosphere- Atmosphere- Ocean- Litosphere.



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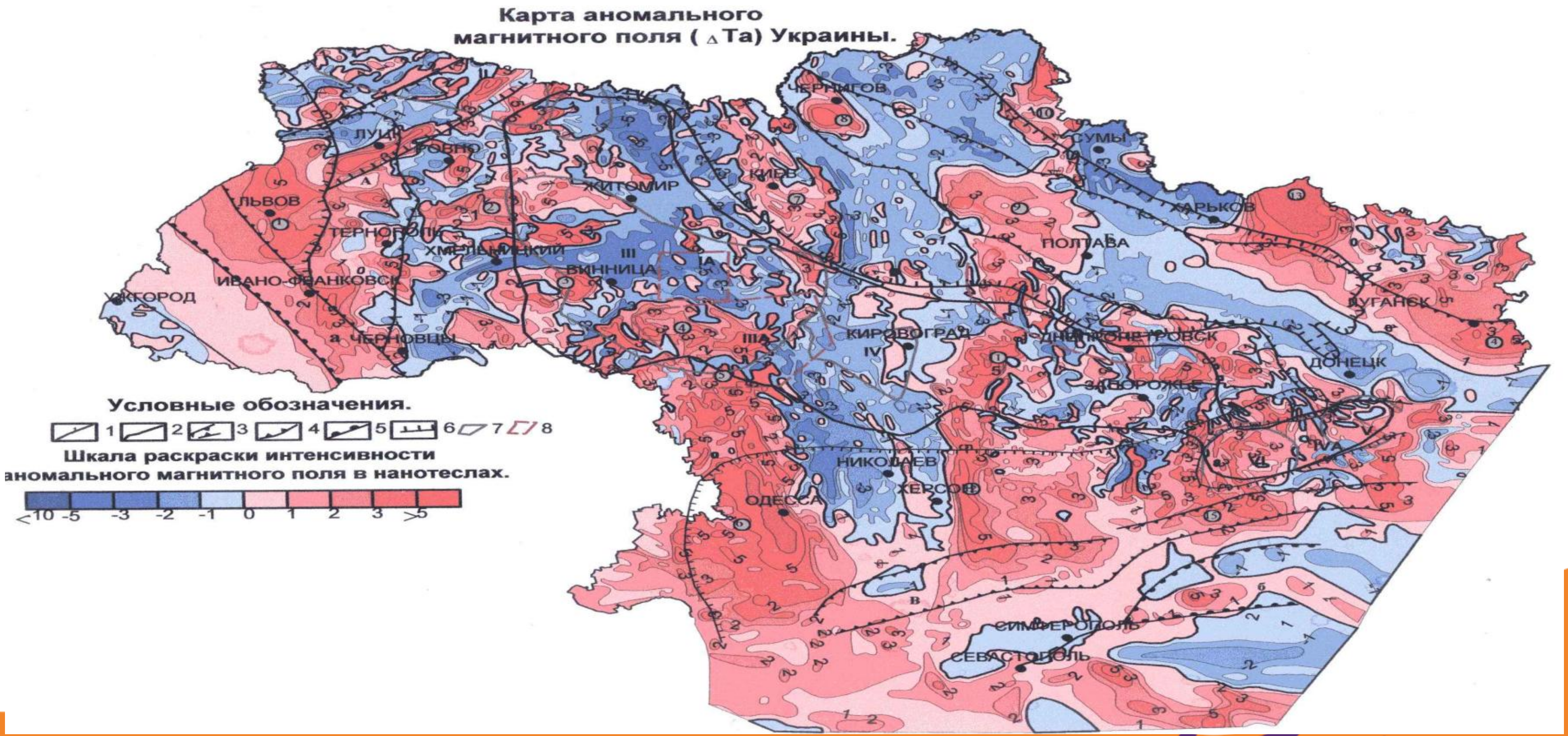
# Magnetic anomaly zone around of Odessa

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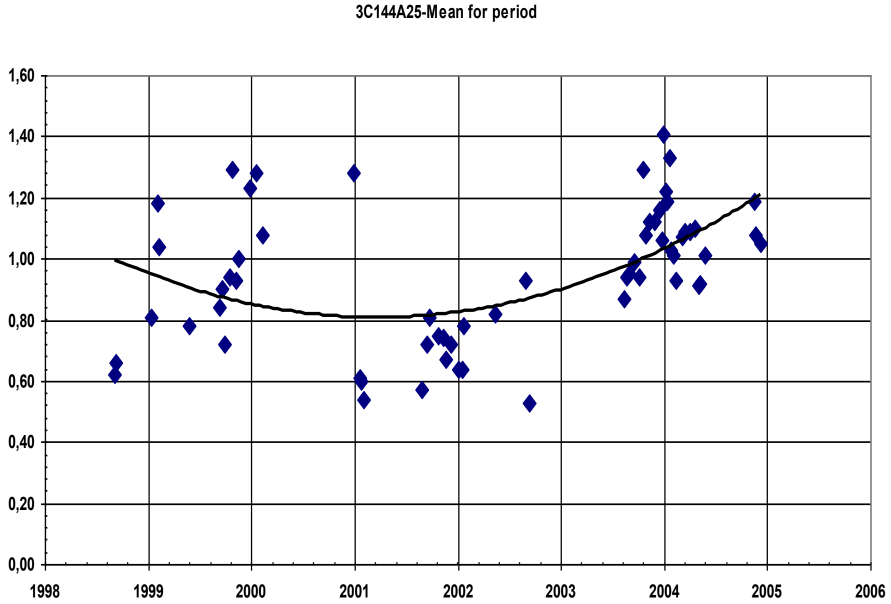
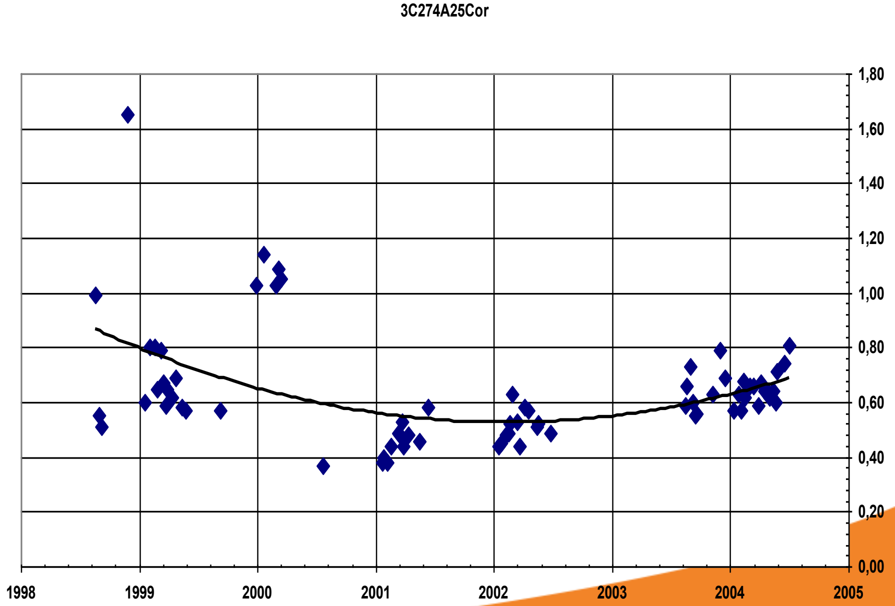
# 23 solar cycle and variation fluxes 3C 144 and 3C 274

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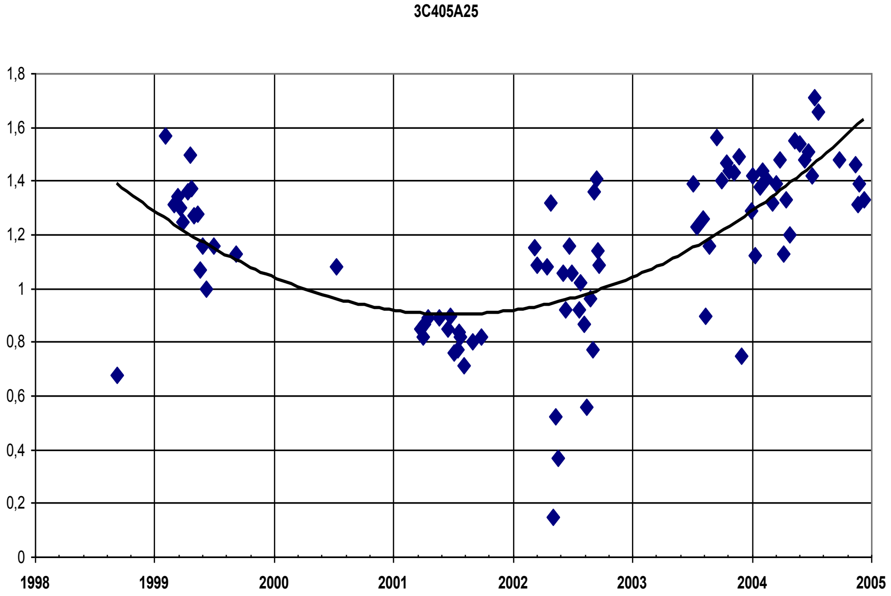
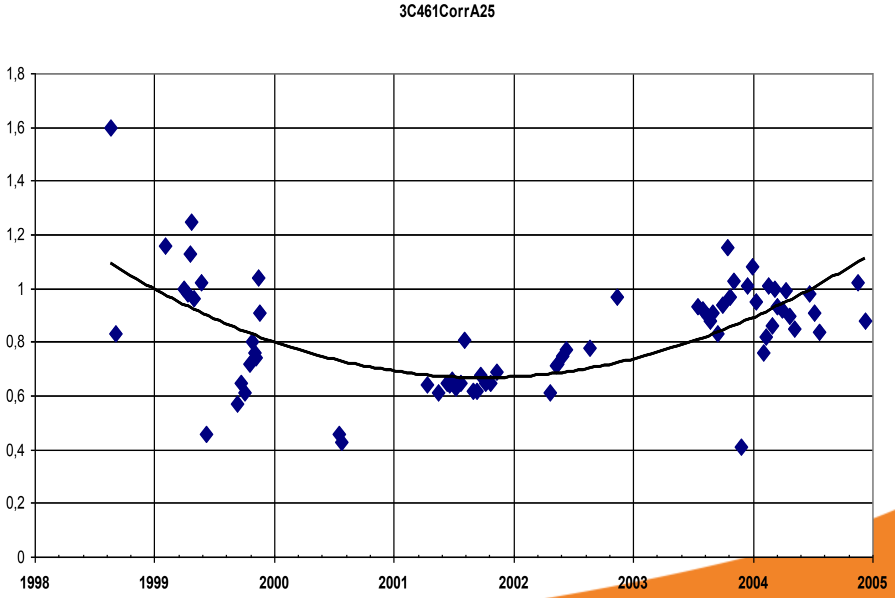
# 23 solar cycle and variation fluxes 3C 405 and 3C 461

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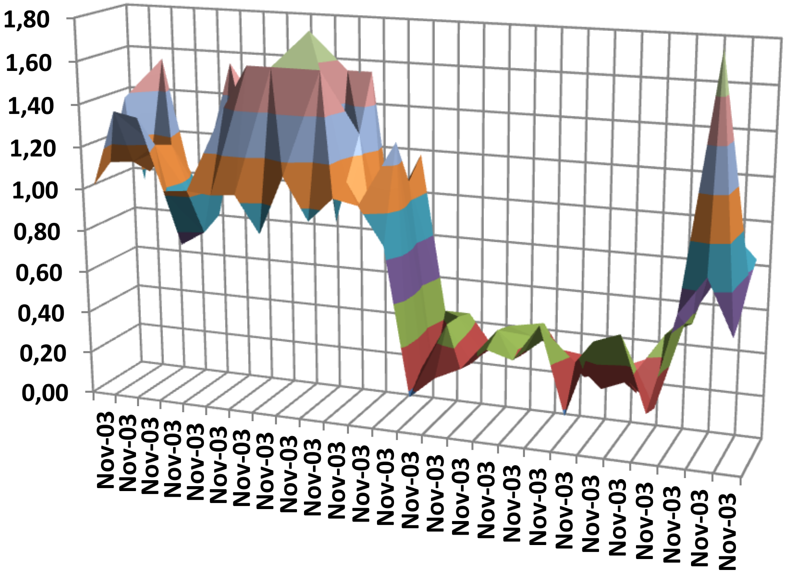
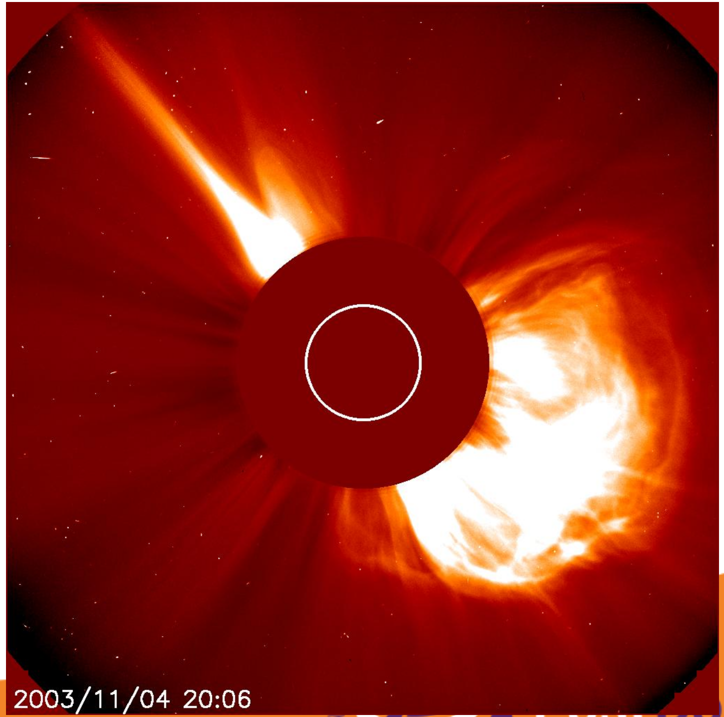
# Nov 2003 year – extremely period solar activity

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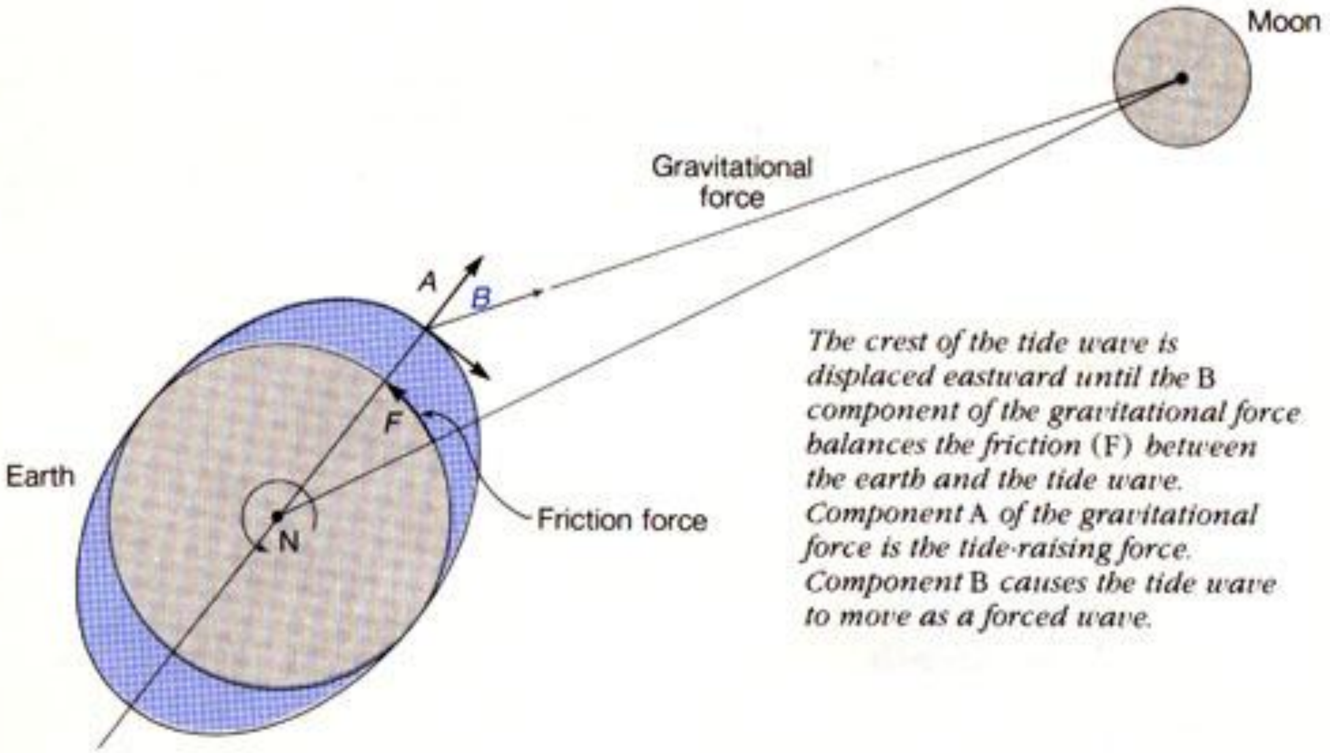
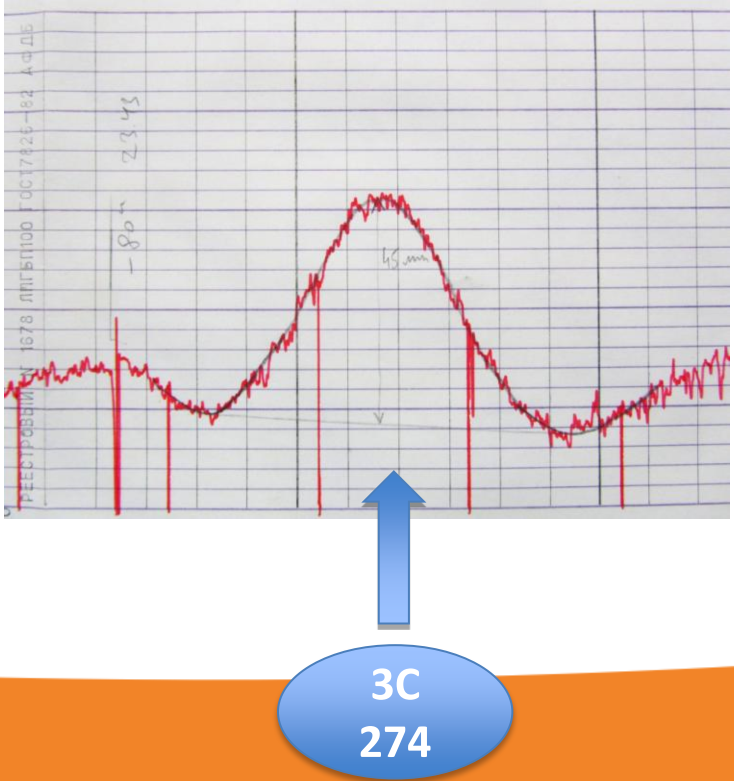
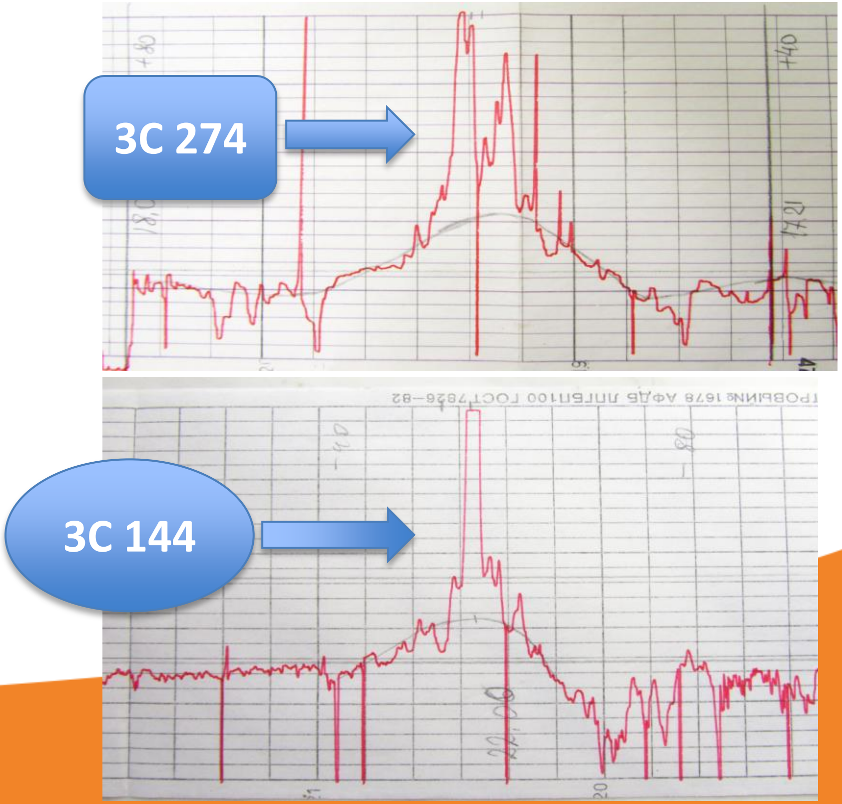
# Moon tides in the Earth ionosphere



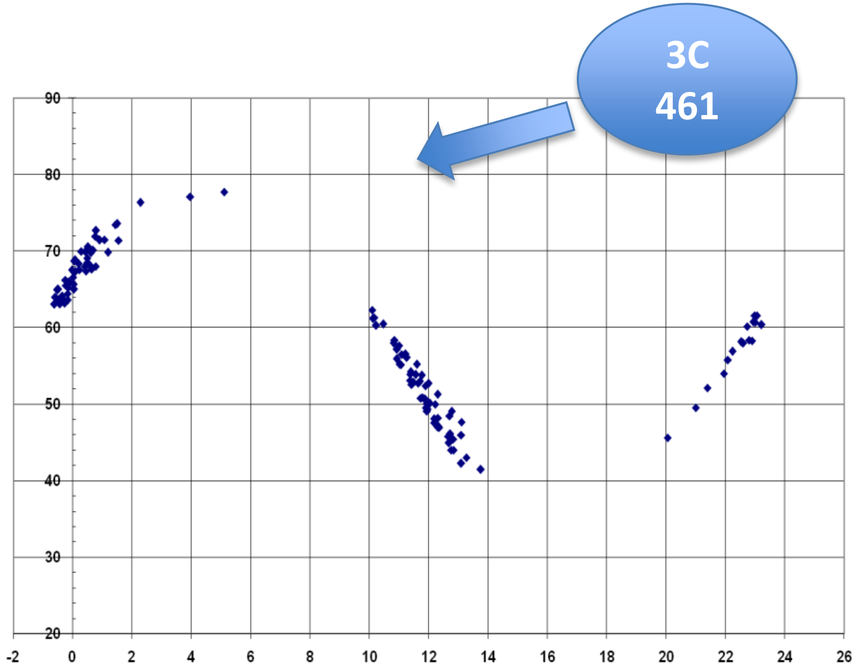

*The crest of the tide wave is displaced eastward until the B component of the gravitational force balances the friction (F) between the earth and the tide wave. Component A of the gravitational force is the tide-raising force. Component B causes the tide wave to move as a forced wave.*

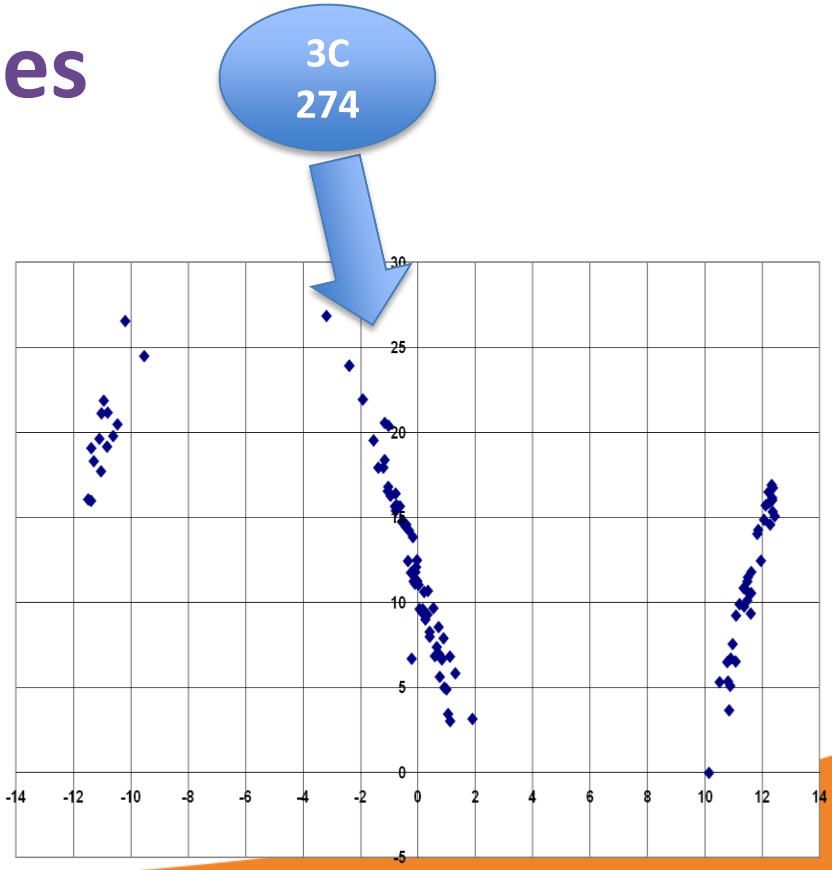
# Ordinary and unusual recordings of radio sources



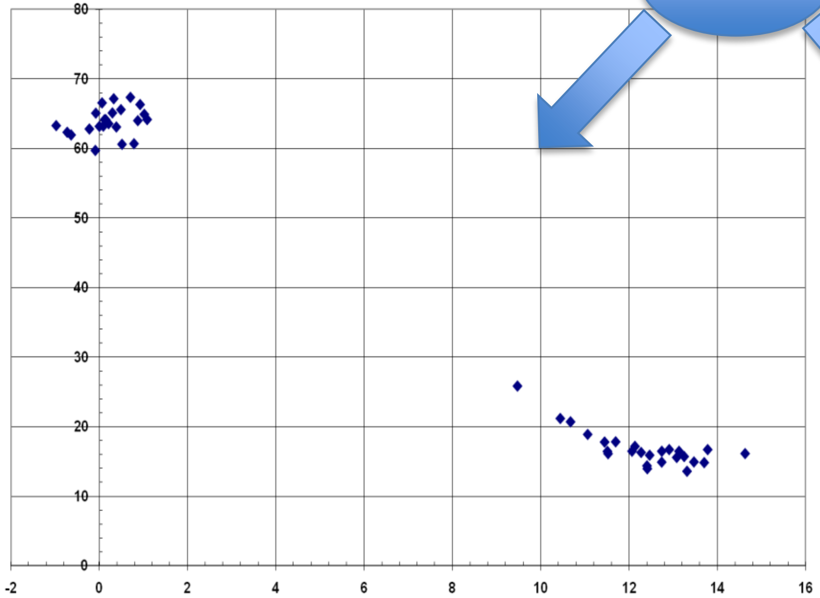
# Registration Moon tides

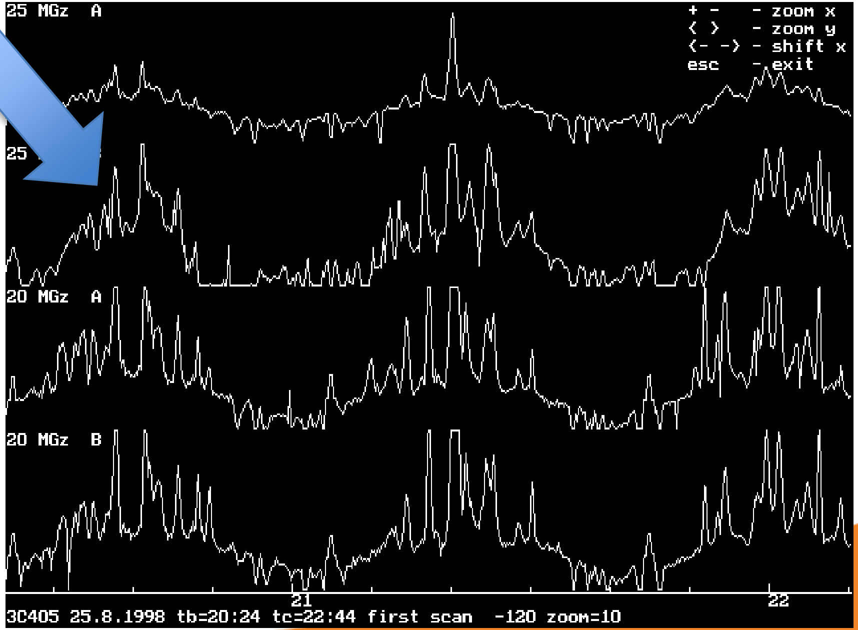


# Registration Moon tides

3C405

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# Conclusions

- Experimentally confirmed the possibility of studying the passage of tidal wave in the earth's ionosphere using the method of "shining" its cosmic radio sources in the decameter wavelength.
- Observed effects of strong flickers of radio sources are associated with the passage of lunar tidal perturbation in the Earth's ionosphere, containing direct and reverse tidal waves. They act like a plasma lens, distorting the shape of the radio source recording.
- Observational data show that the size of tidal perturbation is approximately 30-60 degrees in direct ascent and decline according to different sources.

# Perspectives of monitoring research on radio telescopes from millimeter to decameter wavelengths to solve fundamental and applied problems.

- The organization monitoring program of radio source  from millimetre to decameter wavelengths allows for complex research.
- At the same time, the processes of evolution of radio sources themselves are detected at high frequencies.
- In the area of low frequencies, it is possible to study the state of the space environment by data from variations fluxes in radio sources and their scintillations .
- There is a transitional area of frequencies where processes of its own variability in the radio source and the influence of the cosmic environment are manifested.

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# ! Conclusions !

- 1. An initiative program of quasi-simultaneous observations of intraday variability OJ 287 lacertide in radio and optical ranges was carried out.
- 2. In radio range, main quasiperiods have values ≈ 15, 3-4 days, and possibly ≈ 1.4 months. Possible periods of intraday variability in radio range ≈ 5 and 2-3 hours with minimum characteristic variability times 1.4 hours (6.7 GHz) and 0.6 (6.1 GHz) hours.
- 3. In optical range, IDV was irregular. Long-term possible quasiperiods ≈ 60, 36-37, 13 days.
- 4. The optical flare on April 2 corresponds to minimum flux density at frequency 6.7 GHz. Increased brightness in optical range on April 6 may correspond to small and sharp increase in flux density at 6.7 GHz on April 7.

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# ! Conclusions !

- **5. Approximation by sinusoids observation fragment of 3C 273 quasar from April 5 to 8 (where there are most points of flux density), showed best coincidence with sinusoids periods 12.4, 9.3, 5.5 hours. It should be noted that close to regular (≈ 3 - 4 - 5 hours) 3C 273 brightness variations were sometimes observed in optical range.**
- **6. Observations from March 28 to April 8 for 3C 273 quasar showed density drop to ≈ 2 Jan, with recovery from April 4.**
- **7. Observations on July 23–26 at frequencies 5 and 6.1 GHz showed presence quasiharmonic IDV appearance only on July 25, with characteristic times flux density variations about 7 hours and 1 hour. Hourly quasiperiod was also observed from observations in Urumqi radio observatory (China) at frequency 5 GHz.**

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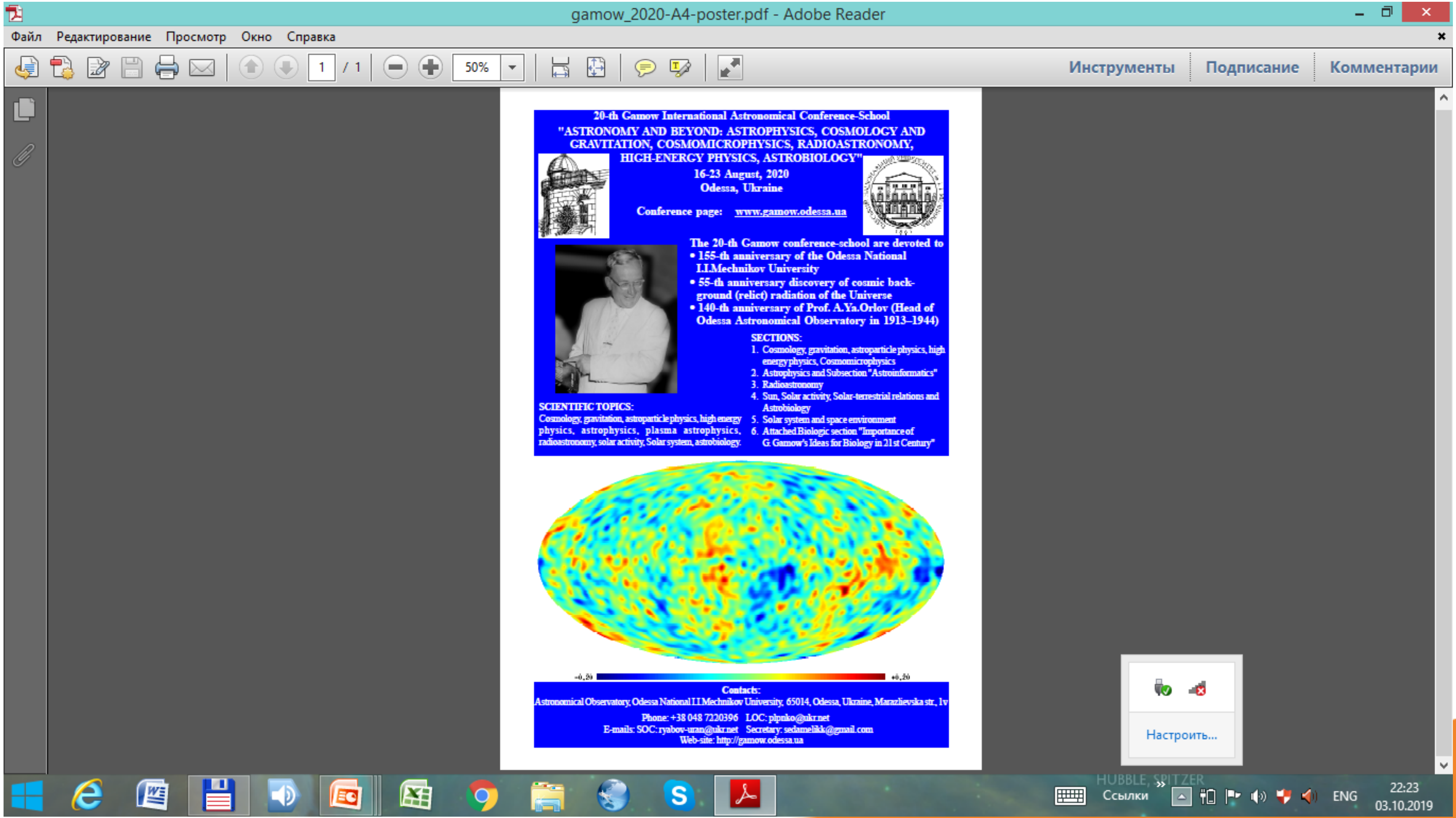
# Joint observations on the Rt-32 radio telescopes in Ventspils and Zolochev.

# Joint research programs on the radio telescopes UTR-2, GURT, URAN systems (Ukraine) and Lofar systems.

**Important area of cooperation between RI NAS Ukraine and VIRAC, Latvia is joint study remnants of supernova explosions (Crab Nebula, Cassiopeia A), radio galaxies (Virgo A, Cyg A), ionospheric and interplanetary scintillations depending on appearance of solar and geomagnetic activity.**

**Using capabilities one of the most advanced low-frequency radio telescope networks in Europe - "URAN" and "GURT" (Ukraine) and "LOFAR" section located in Irbene, Latvia, overlaps wide frequency range, 10 - 80 MHz (URAN, GURT) and 10 - 240 MHz (LOFAR).**

**Joint observations, as well as their comparison with extensive database archival observations on phased arrays "URAN", "UTR-2", will provide new information on evolution supernova remnants, structure of solar wind, especially in region the Sun Supercorona, and ionospheric response to solar activity.**

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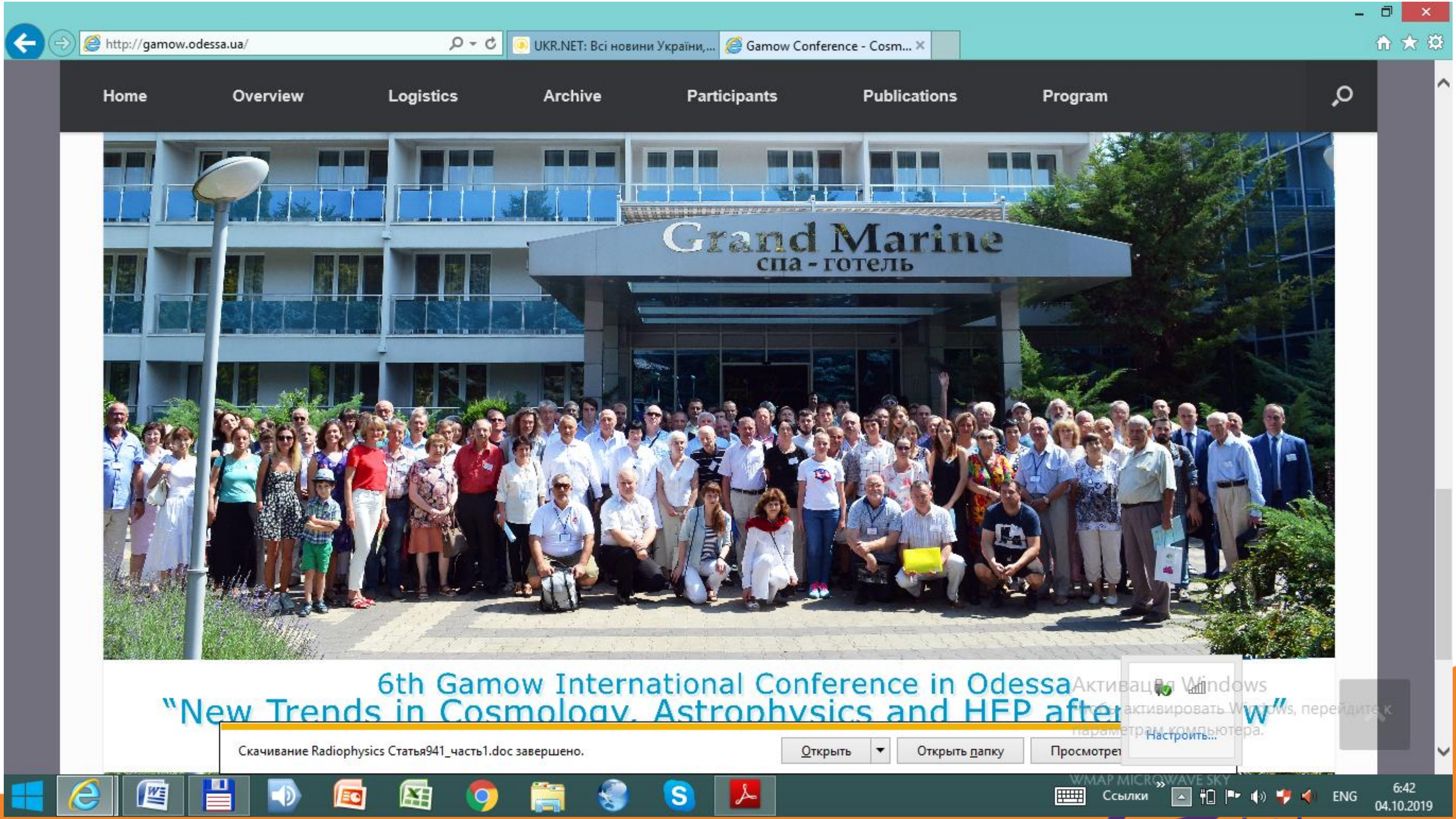
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Активация Windows
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