The search and detection of new pulsars at 111 MHz

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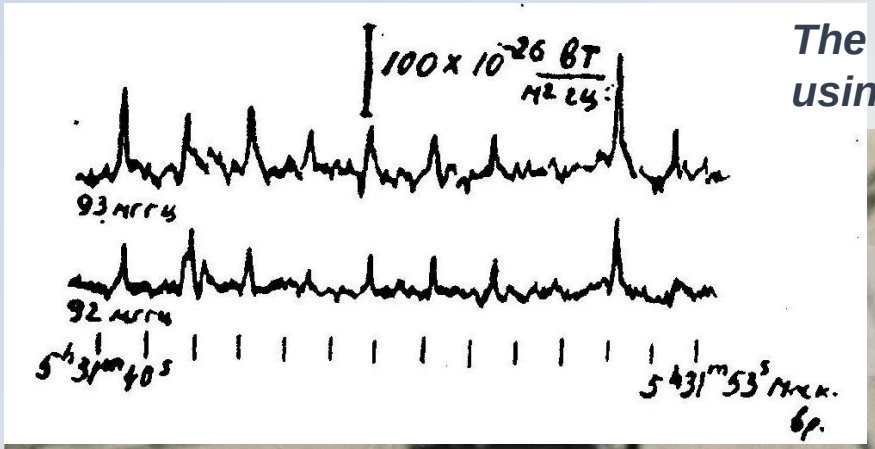
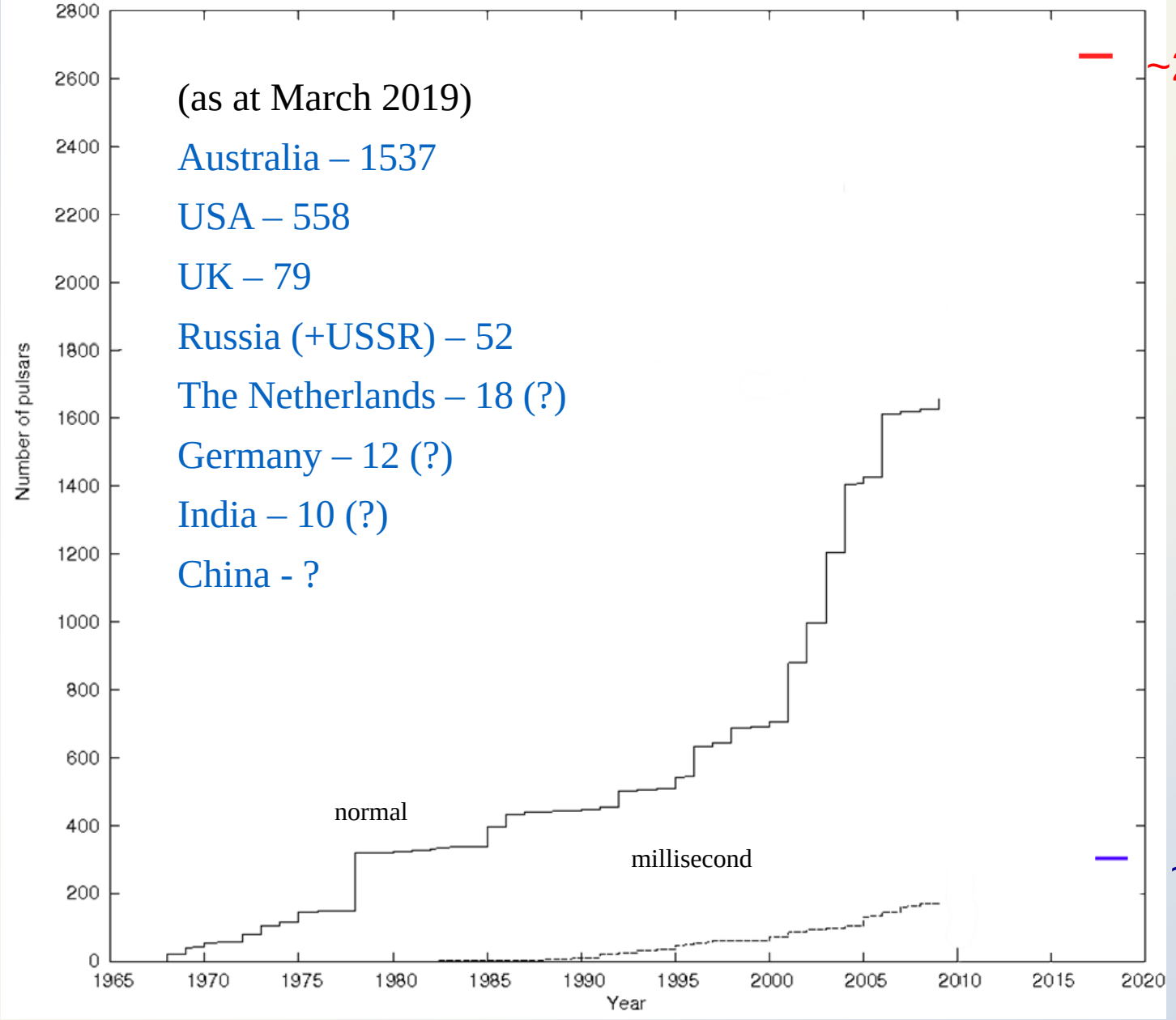


The record of the pulsar CP 1919 on 26.04.1968 using the Cross telescope.

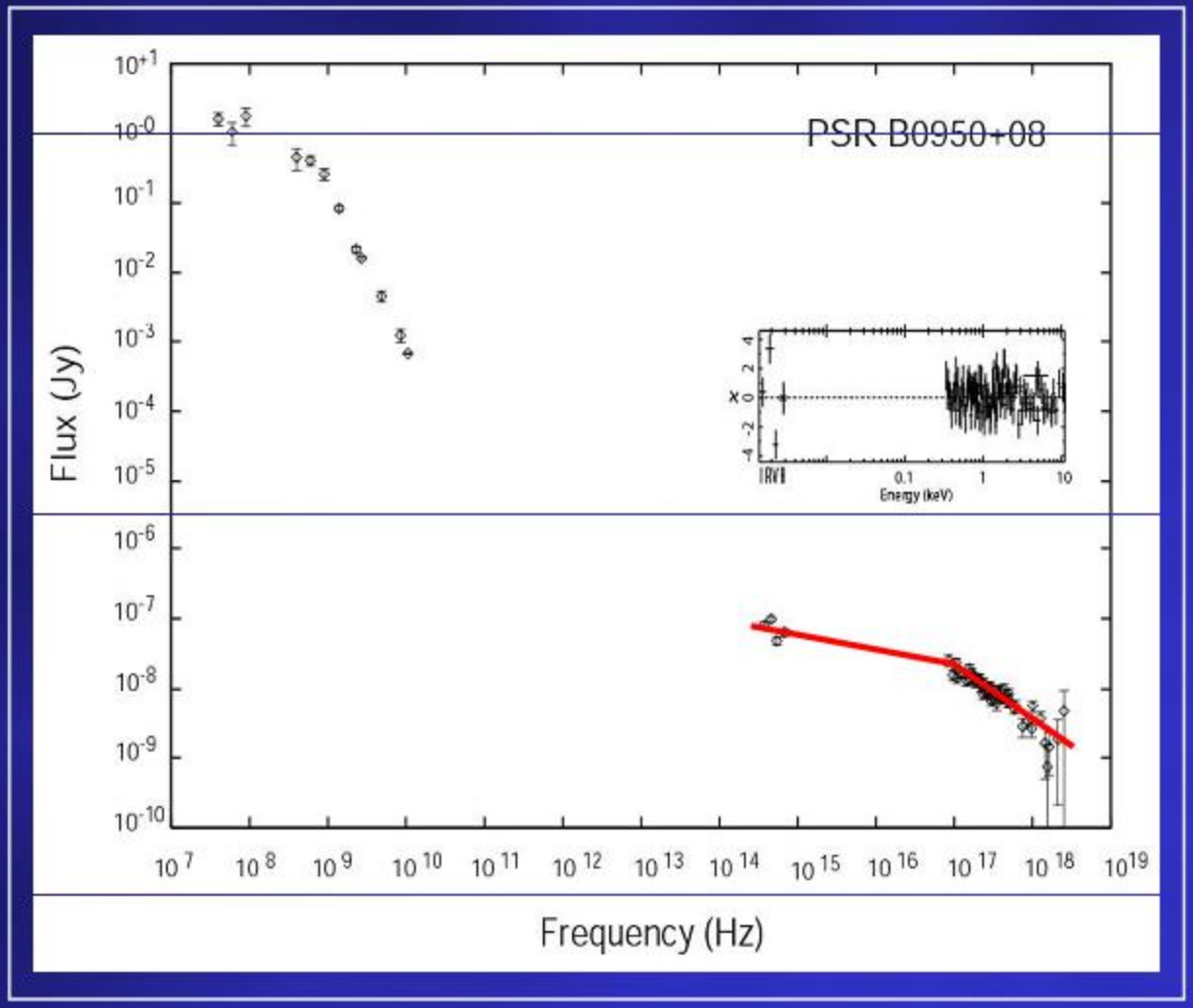
Prof. Viktor Vitkevich was the first leader of pulsar investigations in Pushchino.

5 PSRs: *Vitkevich et al., 1969, Shitov et al., 1980, 2009*

Almost 2700 pulsars and counting…



Multi-wavelength emission spectrum: B0950+08



- Optical to X-ray d
  → broken power law

$$\alpha_1 = 1.27^{+0.02}_{-0.01}$$

$$\alpha_2 = 1.88^{+0.14}_{-0.11}$$

$$E_{break} = 0.67^{+0.18}_{-0.41}$$

Optical data taken with the VLT FORS1 (Zharikov et al. 2003)

Radio data from Malofeev et al.(1994)

Pushchino Radio Astronomy Observatory

PRAO is around 120 km to South from Moscow. There are 45 astronomers and over 50 engineers those are working in PRAO these days. Now PRAO is the Branch of the LPI, and a part of the LPI Astro Space Center (together with Kardashev's team in Moscow)

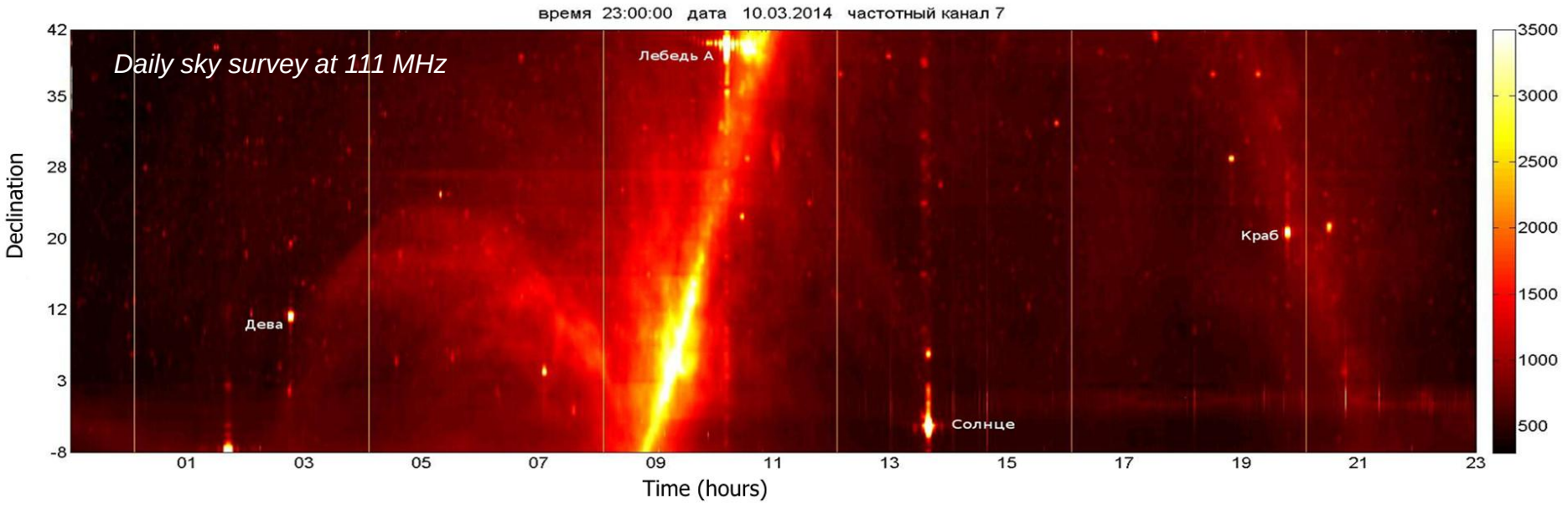
There are three large radio telescopes in PRAO:

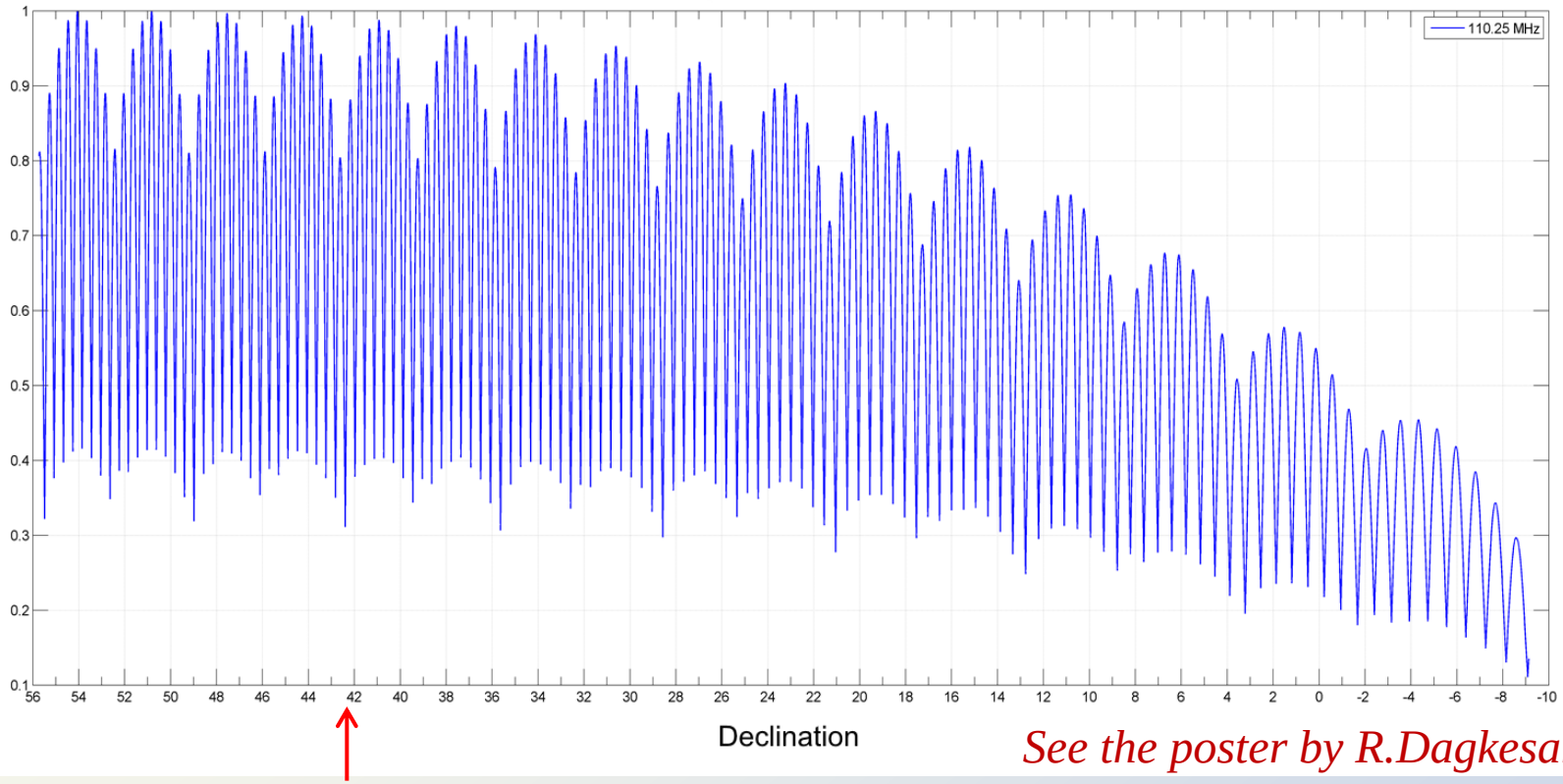
DKR-1000 is a wide-band (30-120 MHz) Cross-Type Meter-Wave-Lengths Radio Telescope.
Two arms of 40m x 1 km.

LPA is a large phased array of 16384 full-wavelength (λ = 2.7 m) dipoles.
Total size is 187m x 384m

RT-22
is 22-meter full-steerable dish
λ_{mni}=8mm

See more detail on the poster by R.Dagkesamanskii





See the poster by R.Dagkesamanskii

Since 2013 round-the-clock monitoring of the sky is carried out simultaneously in 96 space beams using the high-sensitivity radio telescope of LPA (Large Phased Array) at the frequency 110.25 MHz. These observations are made under the program of the interplanetary plasma investigation (space weather).

Observations

LPA-3: 111.5 ± 1.5 MHz, 3.3 ^{m} / cos δ, $A_{eff} \approx 47\,000$ m^2
96 beams (0.5^o × 1^o), δ = -9^o ÷ +42^o

The Receivers: 1) 6 × 415 kHz, Δt = 100 ms
2) 32 × 78 kHz; Δt = 12,5 ms
3) 460 × 4.88 kHz; Δt = 2,56 ms

} for the search

90 Gb/day; 35Tb/year

Methods

1. The fast folding: P = 0,5 – 15 s, DM = 0 – 200 pc/cm^3
2. Fourier power spectra: 2048, 16384 samples (3,5 min)
3. Summed power spectra: ~1300 days (the increase of SNR is 20-30 times)

Criteria of pulsar detection

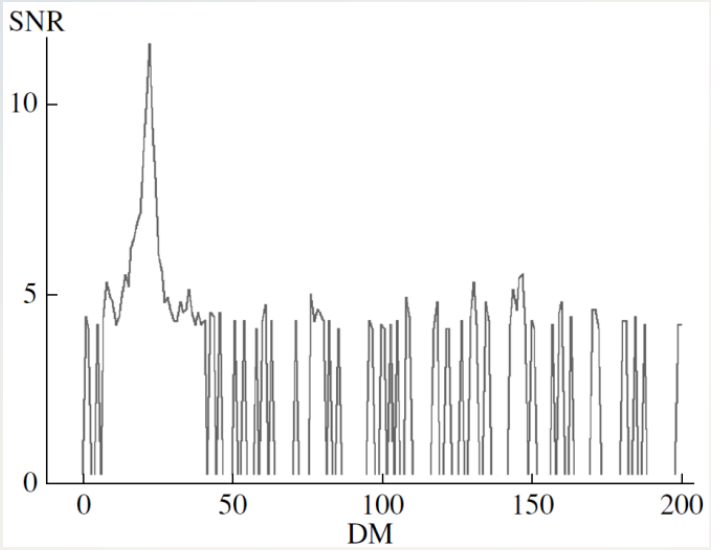
a) the repeatability of the signal in sidereal time;
b) the presence in the summed spectrum of at least two harmonics;
c) the presence of a pronounced maximum on the dependence of the SNR in the averaged profile of the dispersion measure;
d) the existence of at least one record obtained in the 32- frequency channel mode and confirming the existence of a pulsar with an SNR greater than 6;
e) the averaged profiles with a double period should have approximately the same pulse amplitudes.

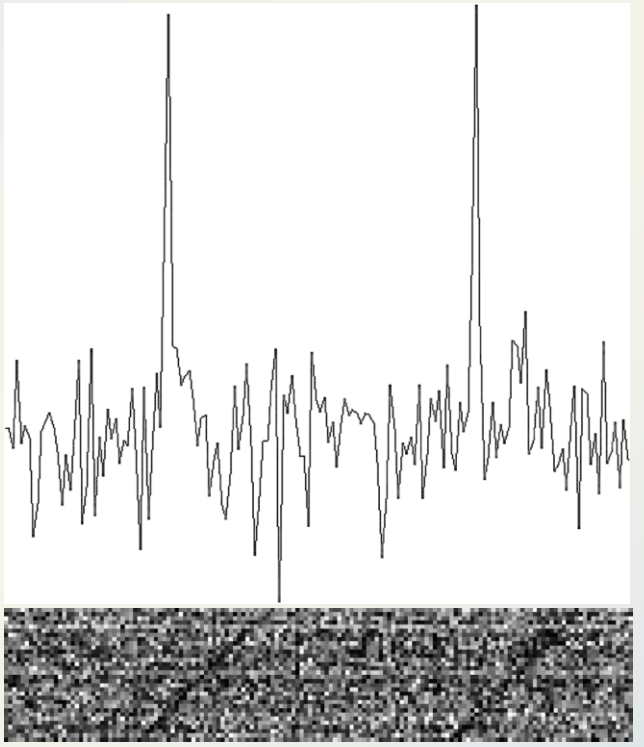
The sensitivity of the search

$$S_{\min} = \frac{SNR_{\min} T_{\mathrm{sys}}}{G\sqrt{n_p \Delta t \Delta \nu_{\mathrm{MHz}}}} \sqrt{\frac{W_e}{P - W_e}} (mJy)$$

Telescopes (size)	v (MHz)	Δv (MHz)	t (s)	S_{min} (mJy)	S_{111} (mJy)	Summing t (s)	Summing S_{111} (mJy)
Effelsberg (100 m)	1360	240	90/1500	0.17/0.05	28.7/8.4	–	–
Parkes (64 m)	1352	340	270/4300	0.61/0.2	101.8/33.4	–	–
Green Bank (100 m)	350	50	140	0.6/3.9 (1.34)	7.3/47 (16.6)	–	–
Arecibo (300 m)	327	57	60	0.3/??	2.6/??	–	–
Pushchino (200×300 m)	111	2,5	180		7/18	2.3×10^5	0.4/1.2

The example of new PSR J0146+3104





Tyul'bashev et al., 2016

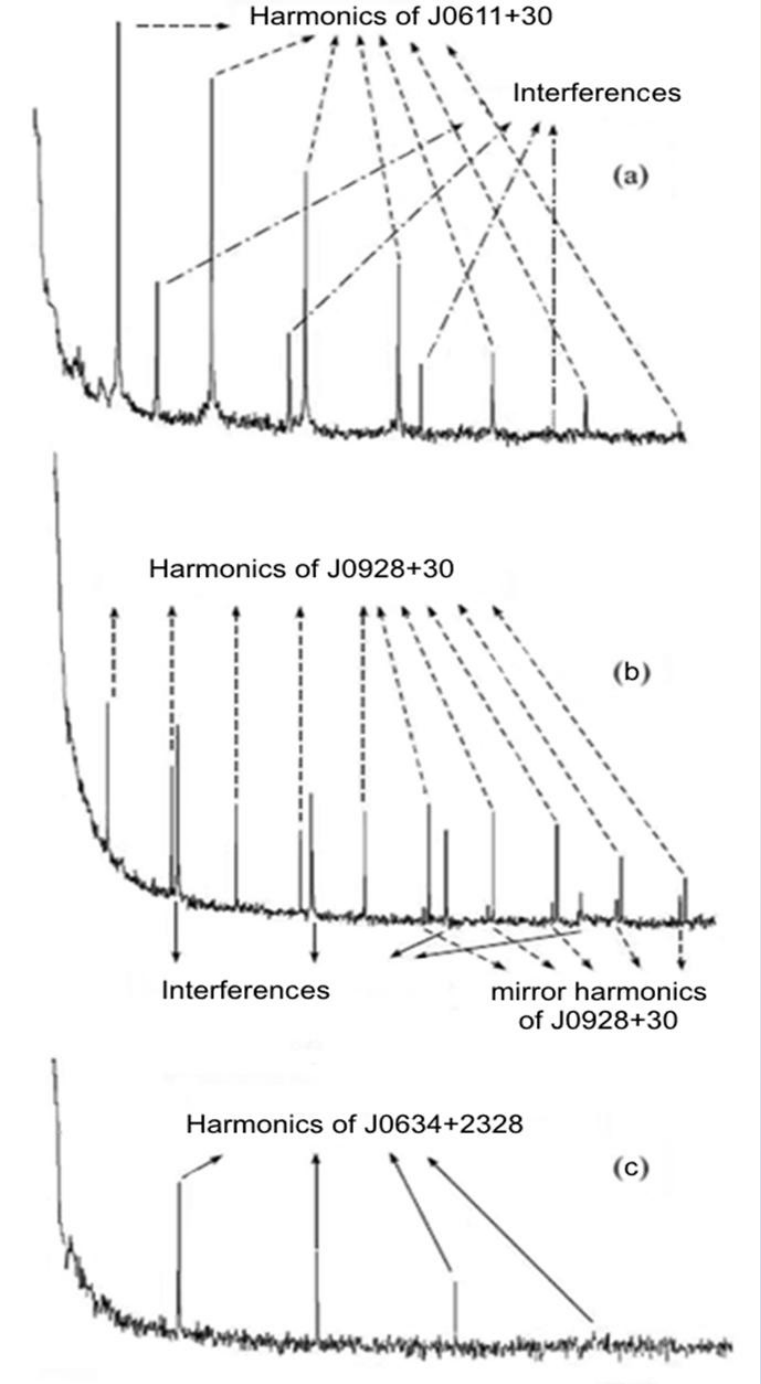
Pulsar name	α_{2000}	δ_{2000}	P (s)	DM (pc/cm^3)	$W_{0.5}$ (ms)	N
J0146+3104	$01^h46^m15^s$	$31°04'$	0.9381	24–26	20	7
J0220+3622	$02^h20^m50^s$	$36°22'$	1.0297	30–50	220	8
J0303+2248	$03^h03^m00^s$	$22°48'$	1.207	15–25	50	4
J0421+3240	$04^h21^m30^s$	$32°40'$	0.9005	60–90	400	4
J0928+3037	$09^h28^m43^s$	$30°37'$	2.0919	20–24	50	16
J1242+3938	$12^h42^m34^s$	$39°38'$	1.3100	25–27	35	14
J1721+3524	$17^h21^m57^s$	$35°24'$	0.8219	19–25	60	18

J0611+30; DM=45 pc/cm^3; P=1.41209s;

S_{430}=1.6 mJy;

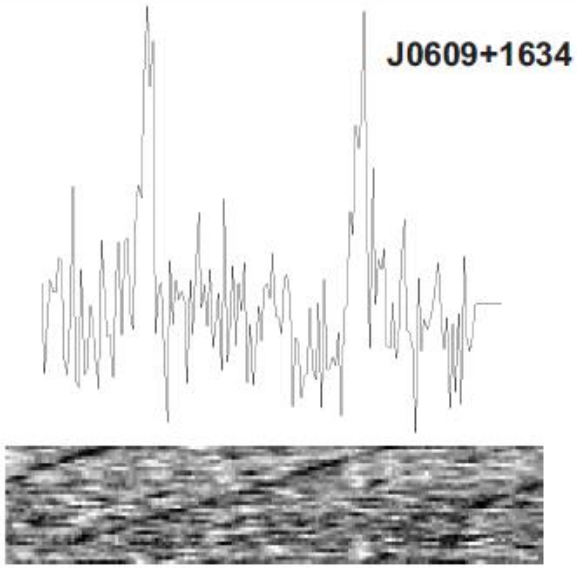
J0928+30; DM=22 pc/cm^3; P=2.0919s;

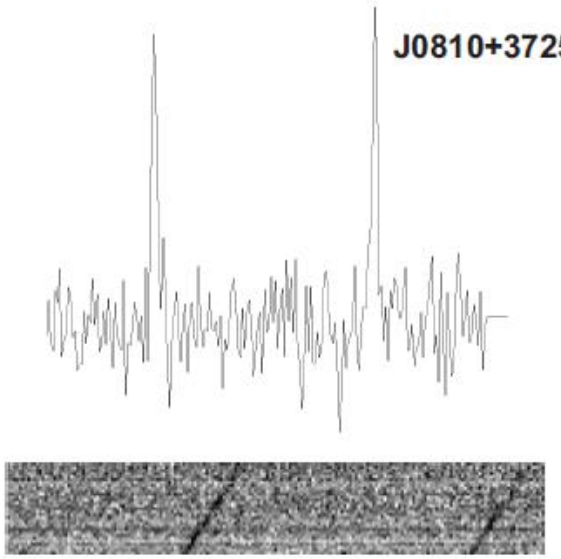
J1644+23; DM=36 pc/cm^3; P=1.2087s;

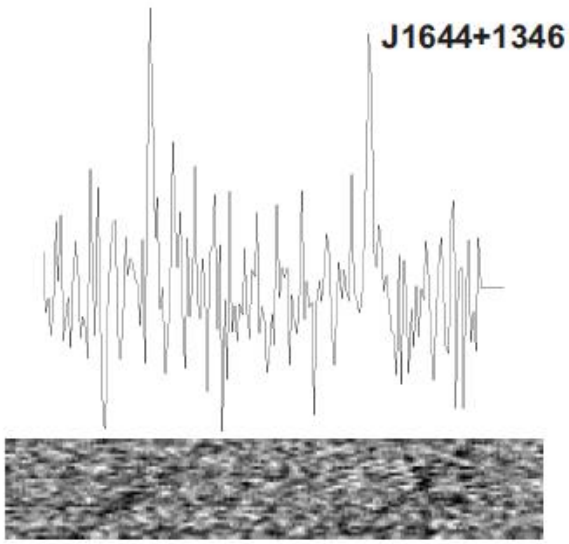


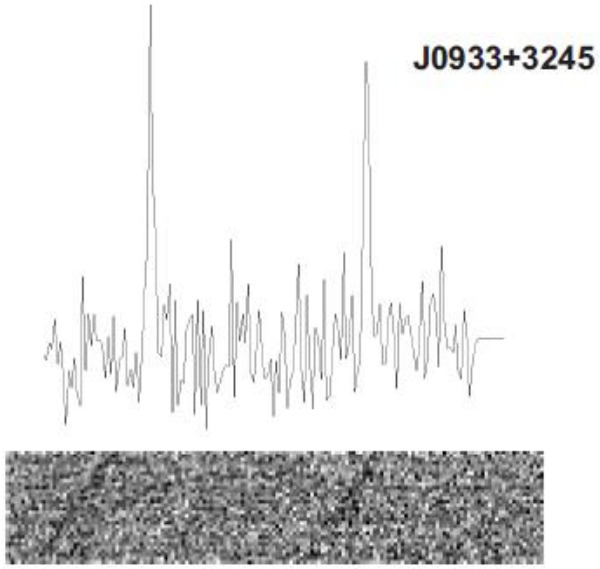
The dynamical spectra and the integrated profiles of 6 new PSRs

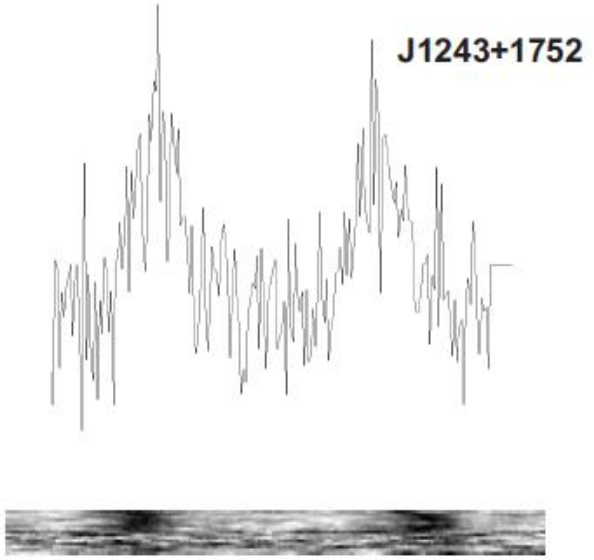
Tyul'bashev et al., 2017

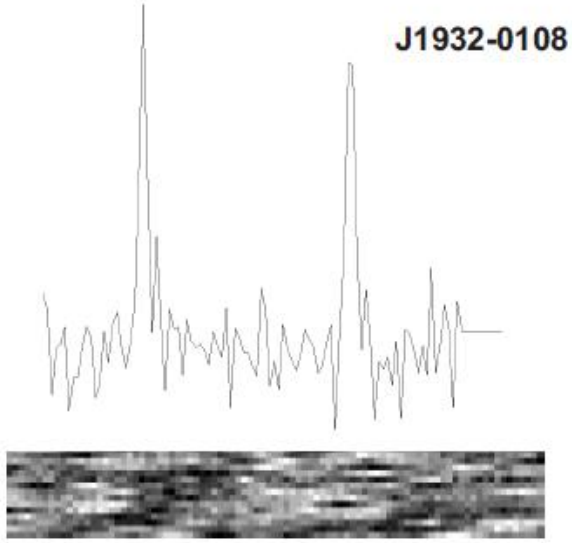




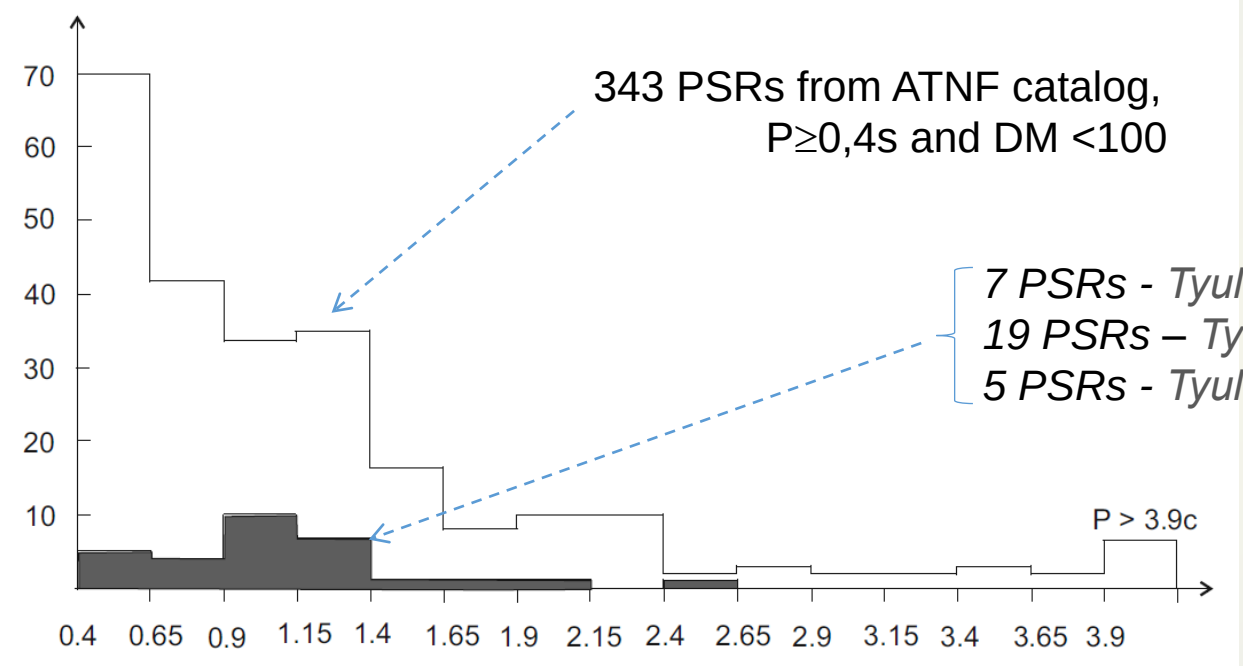








Distribution of periods for ANTF pulsars and pulsars discovered at 111MHz



Resume I:

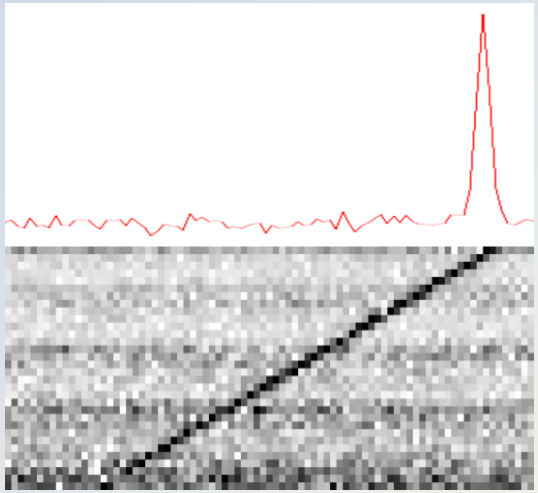
1. We discovered 31 new PSRs and detected 130 PSRs from ATNF-catalog;
2. We have more 50 candidates now and we expect to discover more 100 new PSRs after the all processing.

See more detail on the poster by D.Teplykh

Problems:

1. Interferences;
2. Our sensitivity is not enough to check new extremely weak PSRs in daily observations.

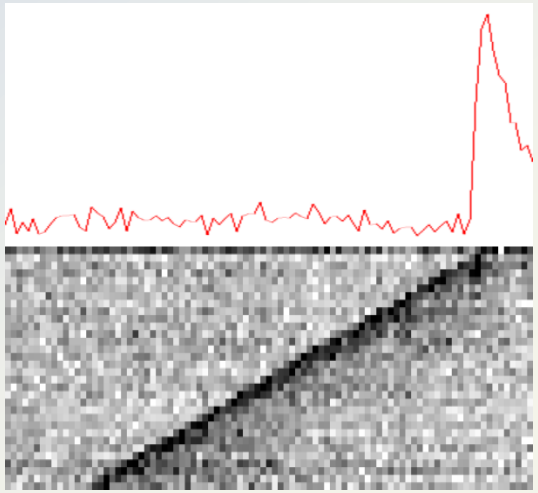
The examples of strong individual pulses



J0528+2200

DM = 50.86 pc/cm^3

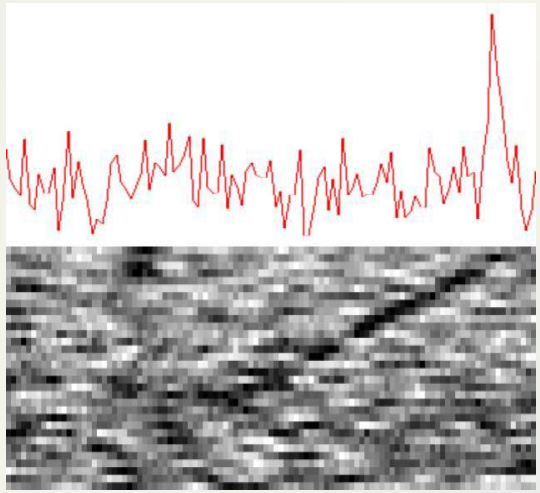
P = 3,7455 s



J0534+2200

DM = 56.77 pc/cm^3

P = 33 ms



J1939+2134 (B1937+21)

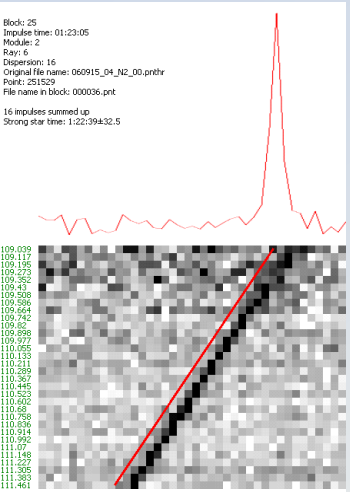
DM = 31 pc/cm^3

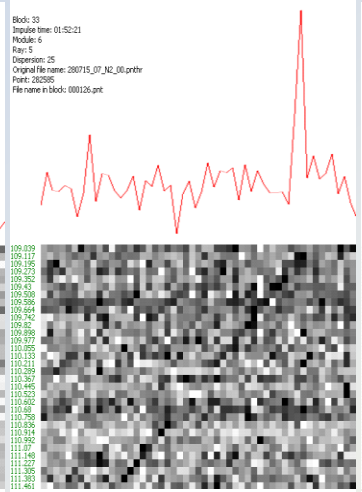
(S_{peak} = 19000 Jy, $<S_{peak}>$ = 80 Jy)

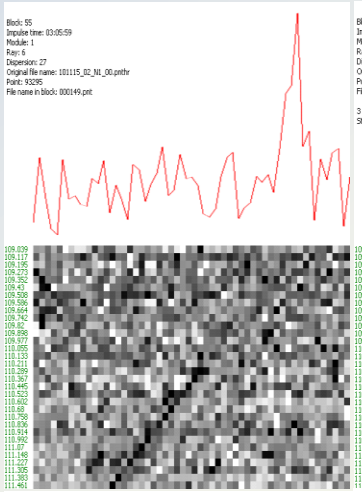
P = 1,55 ms

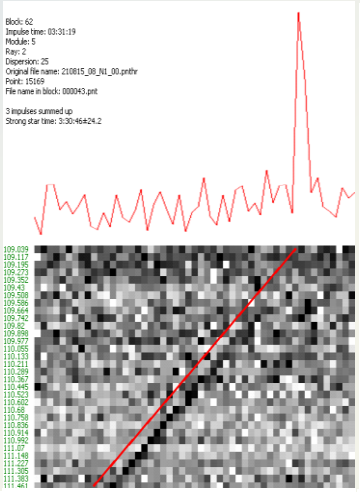
Resume II:

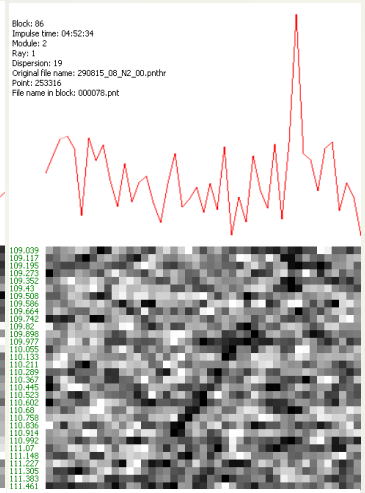
1. The peak flux density of our survey > 2 Jy;
2. We discovered 32 new RRATs ($16_{repeating}$ + $6_{with\ periods}$ +$10_{only\ single\ pulses}$) and detected single pulses for 103 pulsars (25% of ATNF-catalog pulsars with DM < 100, $\delta = -9^\circ \div +42^\circ$). *Tyul'bashev et al.,2018c, 2018d;*
3. There are more 100 candidates for the fast transients.

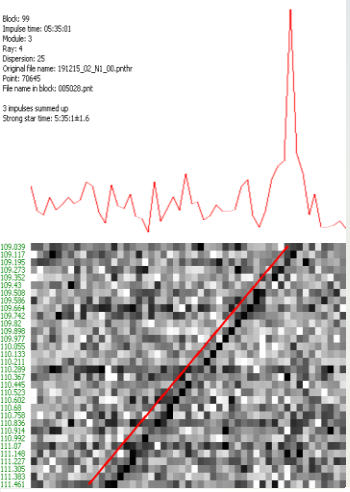

Block: 25
Impulse time: 01:23:05
Module: 2
Ray: 6
Dispersion: 16
Original file name: 060915_04_N2_00.pnthr
Point: 251529
File name in block: 000036.pnt
16 impulses summed up
Strong star time: 1:22:39±32.5

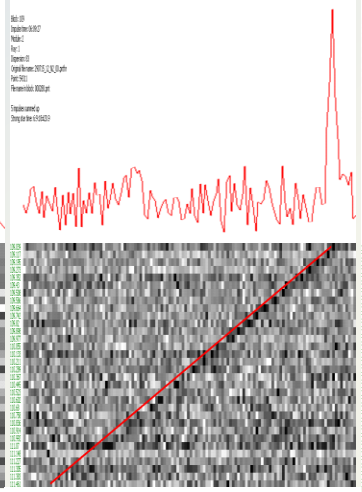

Block: 33
Impulse time: 01:52:21
Module: 6
Ray: 5
Dispersion: 25
Original file name: 280715_07_N2_00.pnthr
Point: 282585
File name in block: 000126.pnt

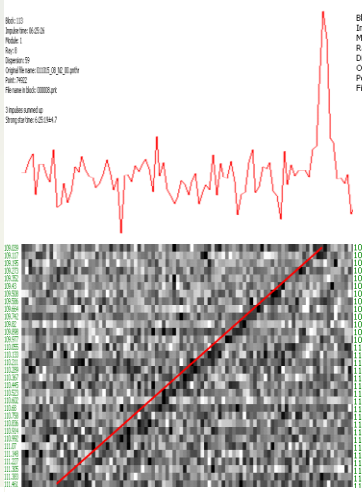

Block: 55
Impulse time: 03:05:59
Module: 1
Ray: 6
Dispersion: 27
Original file name: 101115_02_N1_00.pnthr
Point: 93295
File name in block: 000149.pnt

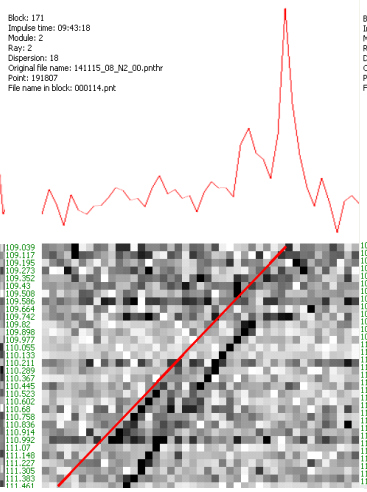

Block: 62
Impulse time: 03:31:19
Module: 5
Ray: 2
Dispersion: 25
Original file name: 210815_08_N1_00.pnthr
Point: 15169
File name in block: 000043.pnt
3 impulses summed up
Strong star time: 3:30:46±24.2

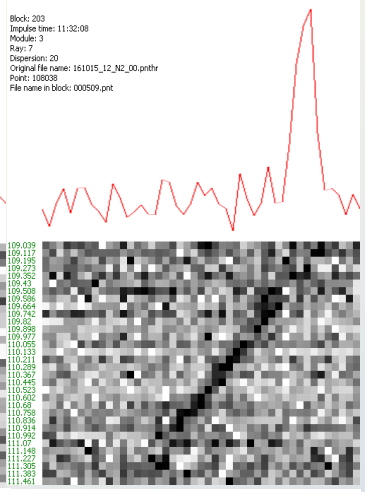

Block: 86
Impulse time: 04:52:34
Module: 2
Ray: 1
Dispersion: 19
Original file name: 290815_08_N2_00.pnthr
Point: 253316
File name in block: 000078.pnt











Block: 99
Impulse time: 05:35:01
Module: 3
Ray: 4
Dispersion: 25
Original file name: 191215_02_N1_00.pnthr
Point: 70645
File name in block: 005028.pnt
3 impulses summed up
Strong star time: 5:35:1±1.6

Block: 171
Impulse time: 09:43:18
Module: 2
Ray: 2
Dispersion: 18
Original file name: 141115_08_N2_00.pnthr
Point: 191807
File name in block: 000114.pnt

Block: 203
Impulse time: 11:32:08
Module: 3
Ray: 7
Dispersion: 20
Original file name: 161015_12_N2_00.pnthr
Point: 108038
File name in block: 000509.pnt

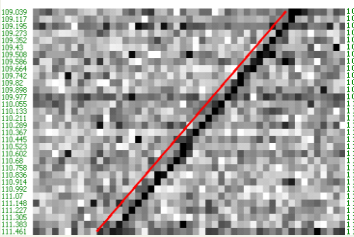
Block: 204
Impulse time: 11:32:32
Module: 5
Ray: 8
Dispersion: 23
Original file name: 110815_16_N1_00.pnthr
Point: 203566
File name in block: 000036.pnt
7 impulses summed up
Strong star time: 11:33:2±26.3

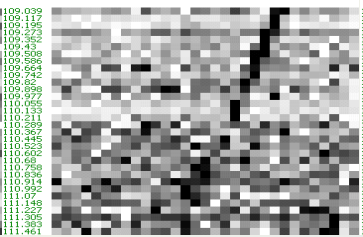
Block: 243
Impulse time: 13:45:58
Module: 4
Ray: 4
Dispersion: 9
Original file name: 231015_14_N2_00.pnthr
Point: 40496
File name in block: 000065.pnt

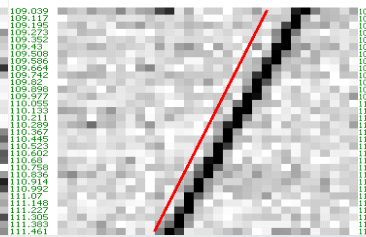
Block: 247
Impulse time: 13:59:53
Module: 6
Ray: 8
Dispersion: 9
Original file name: 230815_18_N1_00.pnthr
Point: 106367
File name in block: 000079.pnt
7 impulses summed up
Strong star time: 14:0:37±40.0

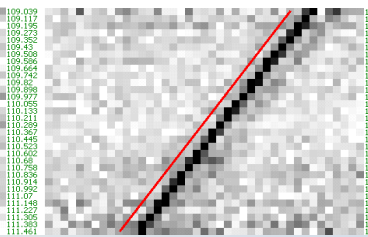
Block: 248
Impulse time: 14:03:37
Module: 3
Ray: 2
Dispersion: 17
Original file name: 191015_14_N2_00.pnthr
Point: 200570
File name in block: 000127.pnt
44 impulses summed up
Strong star time: 14:4:49±38.3

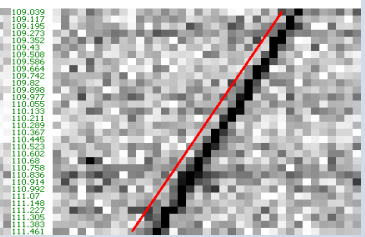
Block: 265
Impulse time: 15:01:55
Module: 5
Ray: 1
Dispersion: 14
Original file name: 310815_18_N1_00.pnthr
Point: 252429
File name in block: 000657.pnt
9 impulses summed up
Strong star time: 15:2:9±39.8







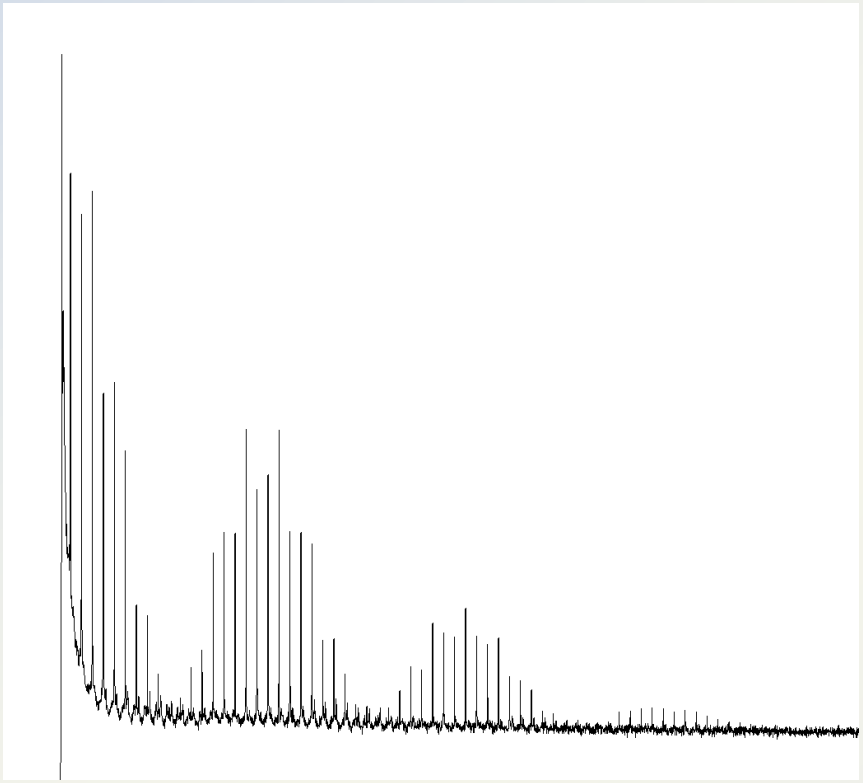




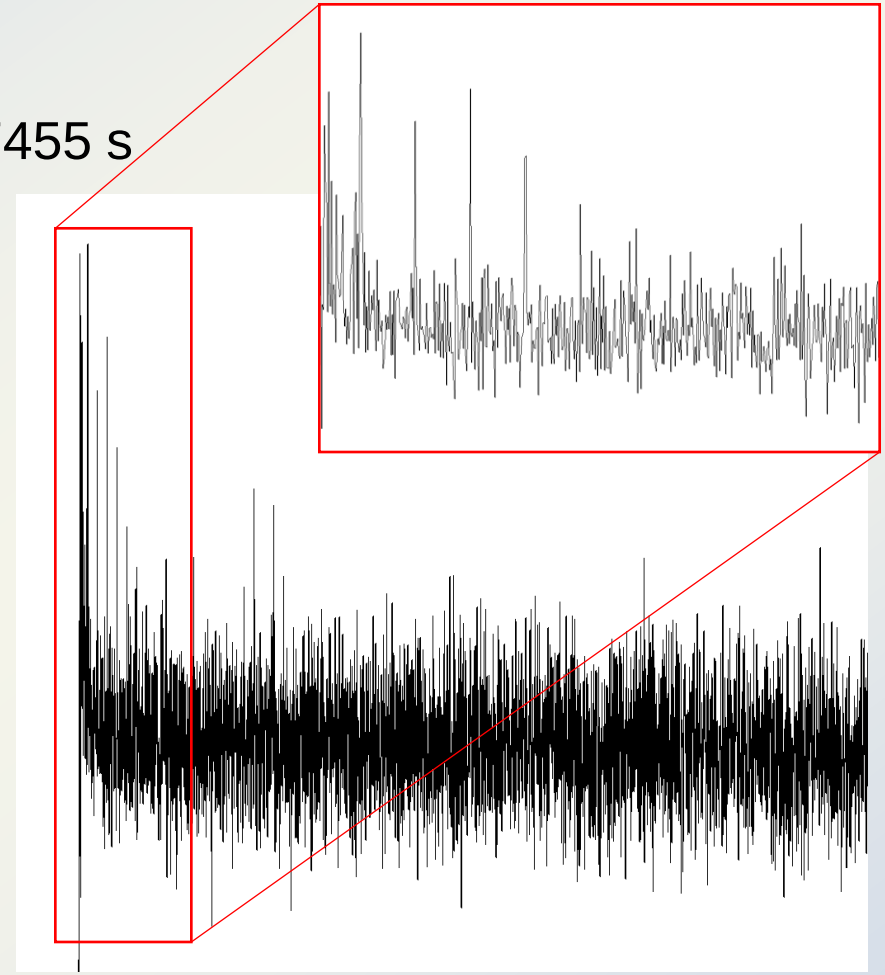
Summed power spectra

Malofeev & Tul'bashev, 2018

PSR J0528+2200 (B0525+21); P=3.7455 s



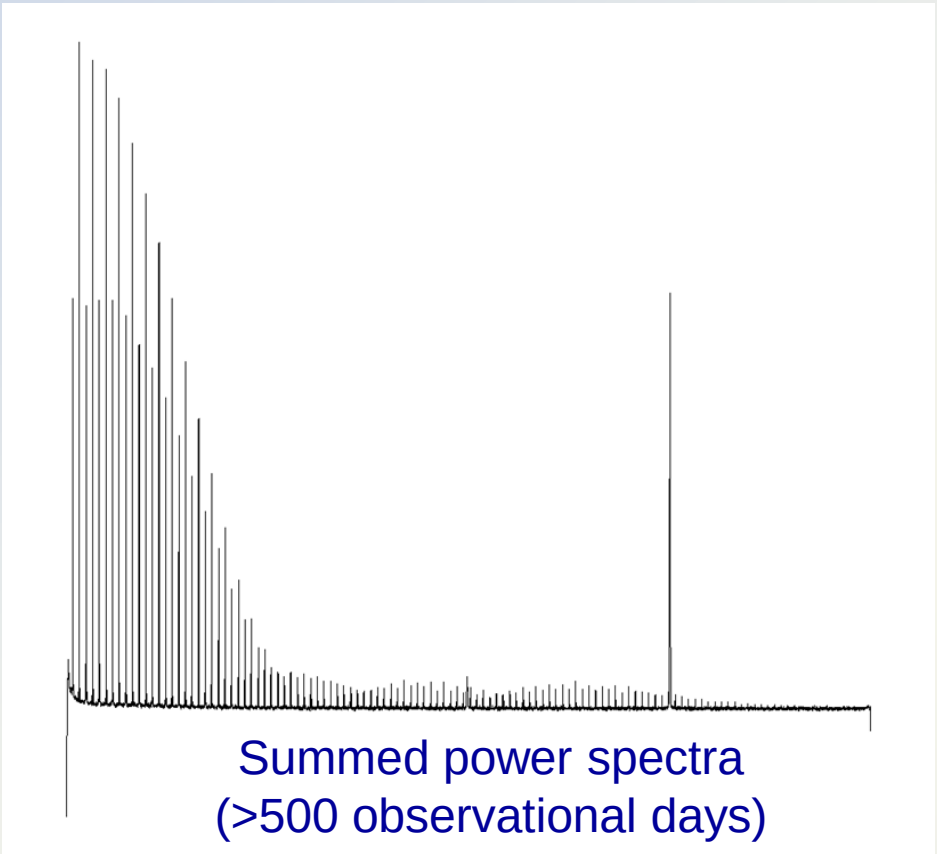
Summed power spectra
(>500 observational days)

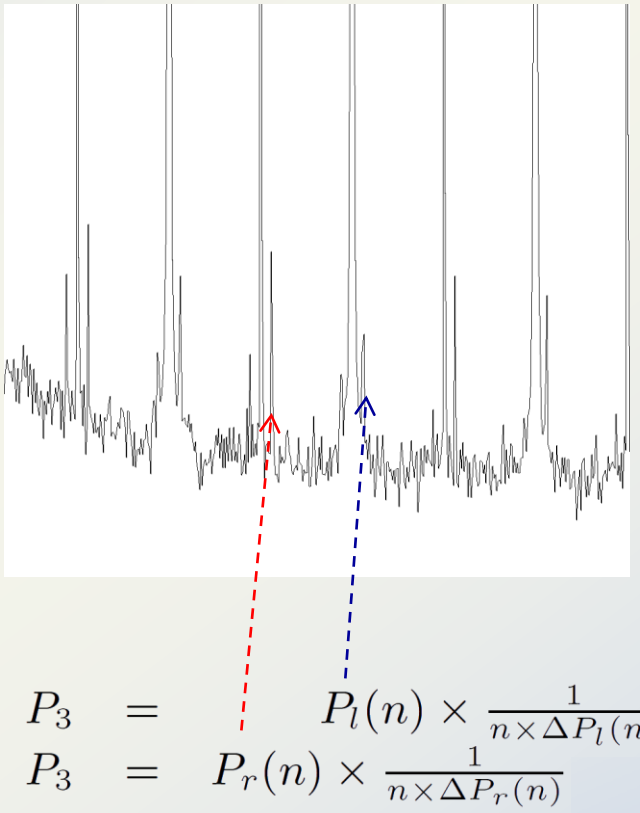


Power spectrum of one observational day
(3 min)

$$P_2 = P_1 / n$$

PSR J0321+3938 (B0320+39); P=3.0321s





Resume III:

1. The value P_2 was estimated for 26 pulsars, and for 15 sources it was made for the first time.
2. The value P_3 was estimated for 13 pulsars, from them for 5 sources they were given for the first time.

See more detail on the poster by D.Teplykh