Radiation mechanisms of astrophysical objects: classics today

Search for the Giant Pulses (GPs) – an extreme phenomenon in radio pulsar emission

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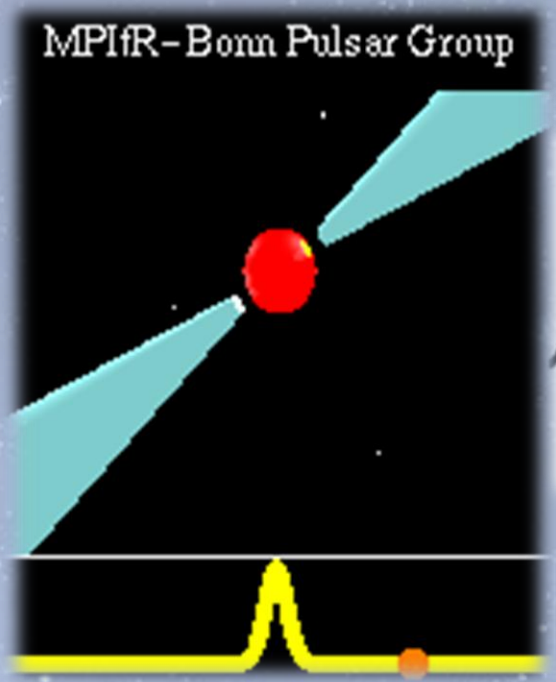
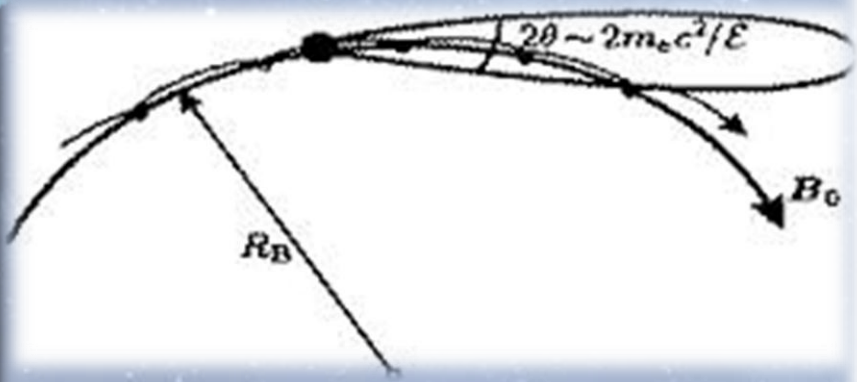
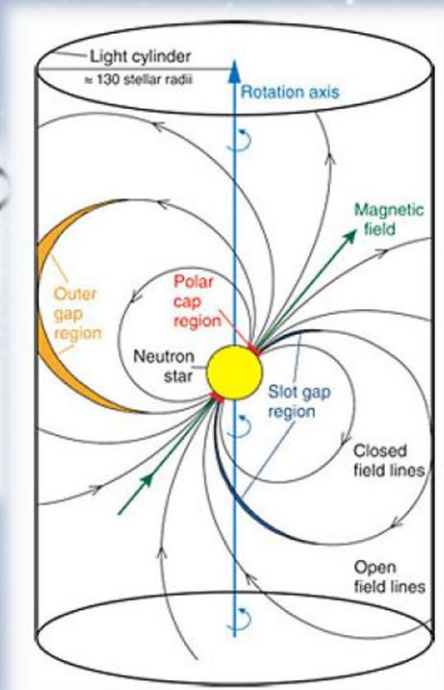
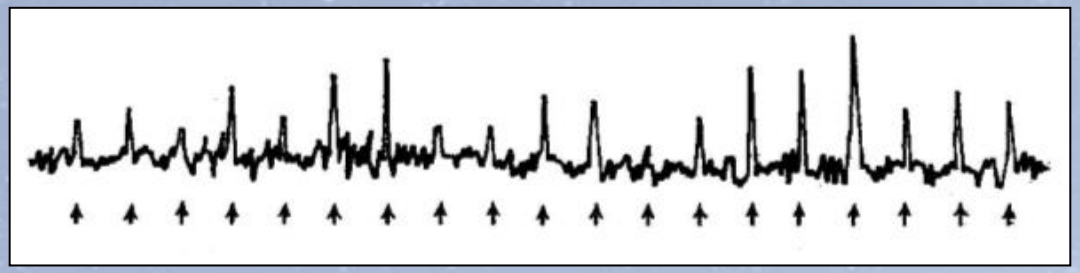
St.Petersburg, September 21-25, 2015

Radio pulsars





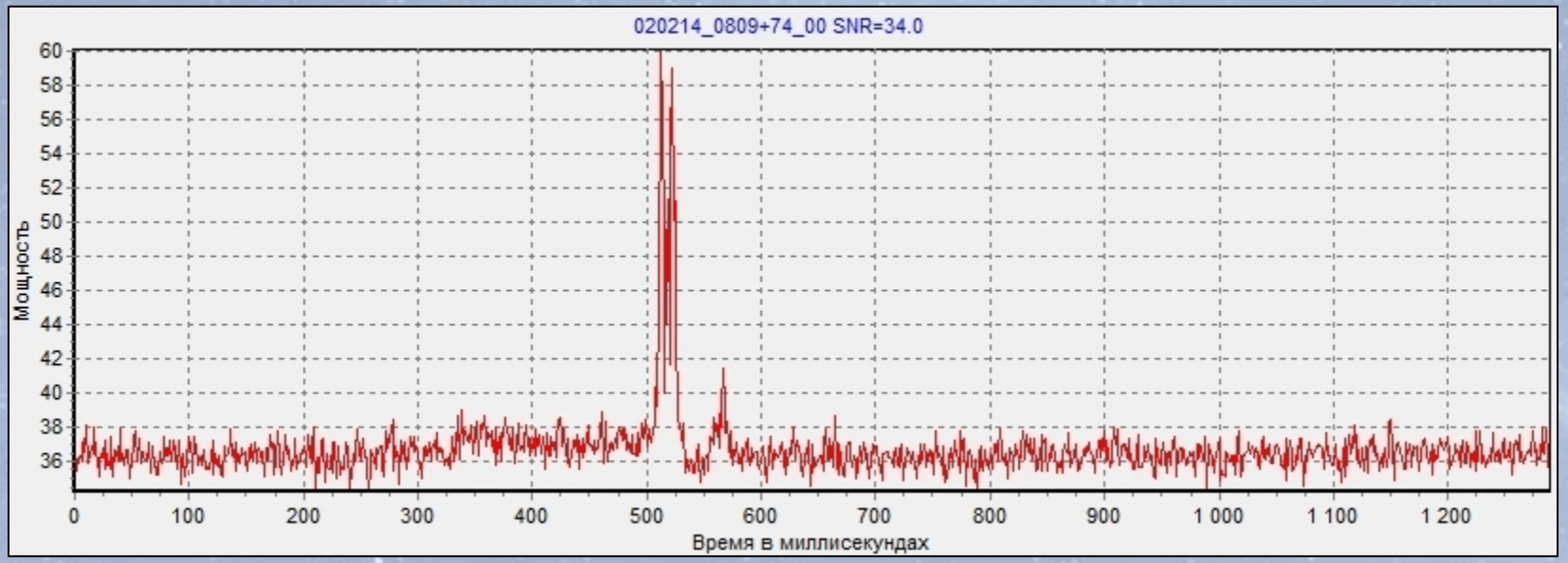


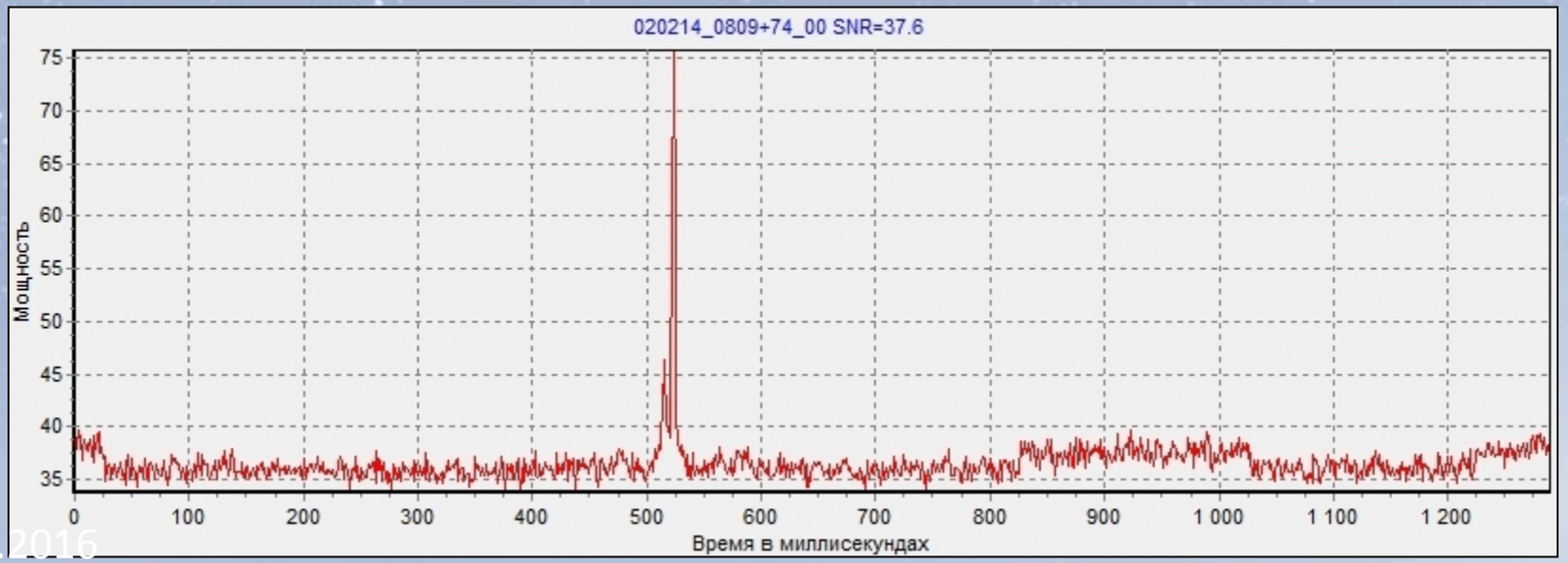


strictly periodic signals

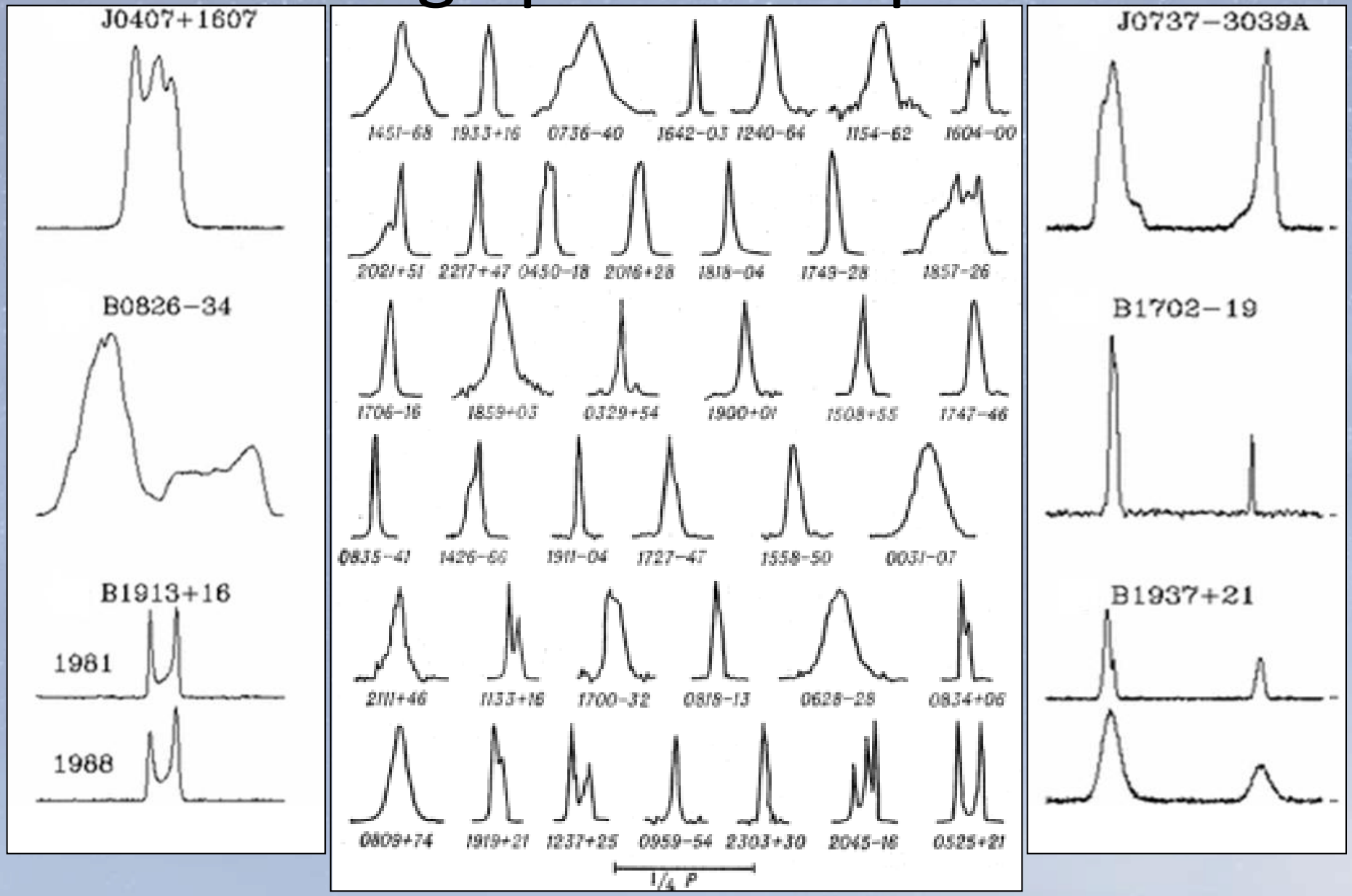
$$B \approx 10^{12}\ G\,;\ E \approx 10^{10}\ V/cm$$

Individual pulses and average profile of pulsar



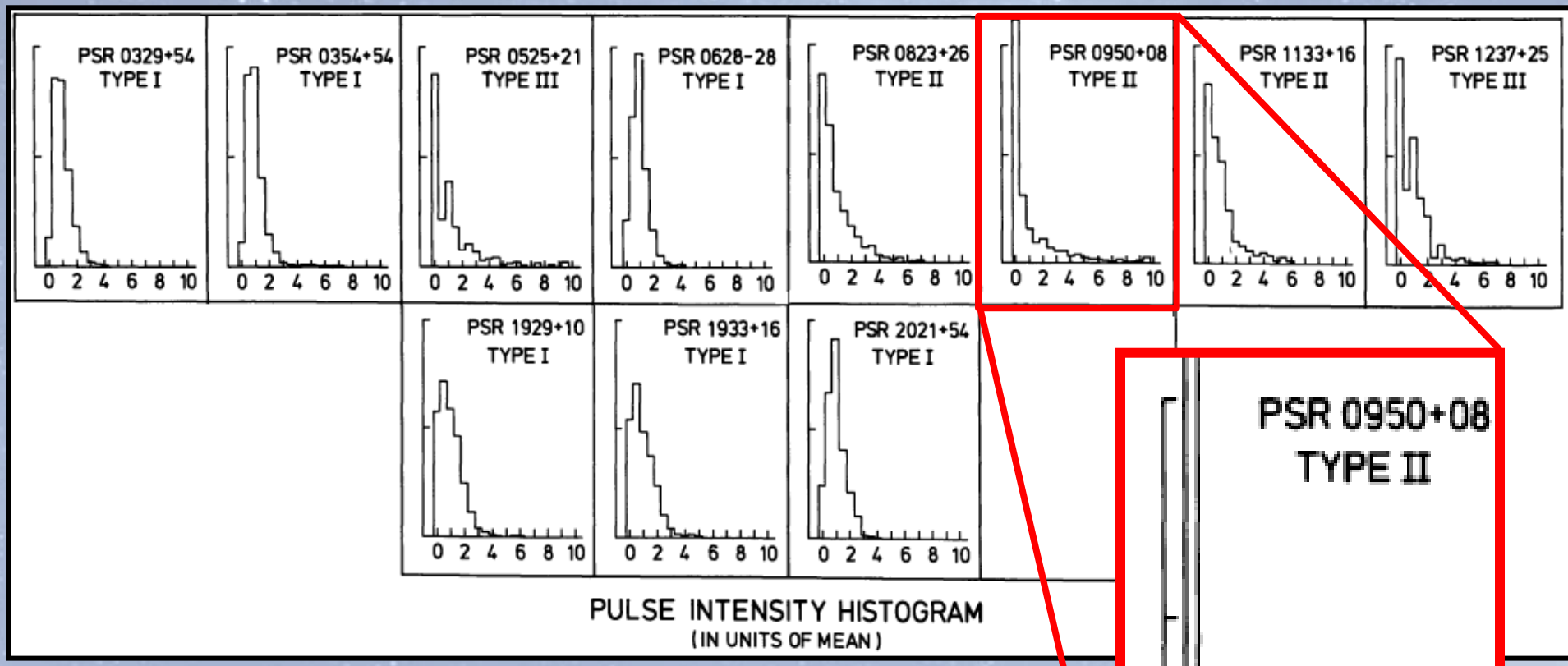


Average profiles of pulsars



average energy distribution of pulses by phase of period.

Histograms of individual pulses energy distribution of pulsars

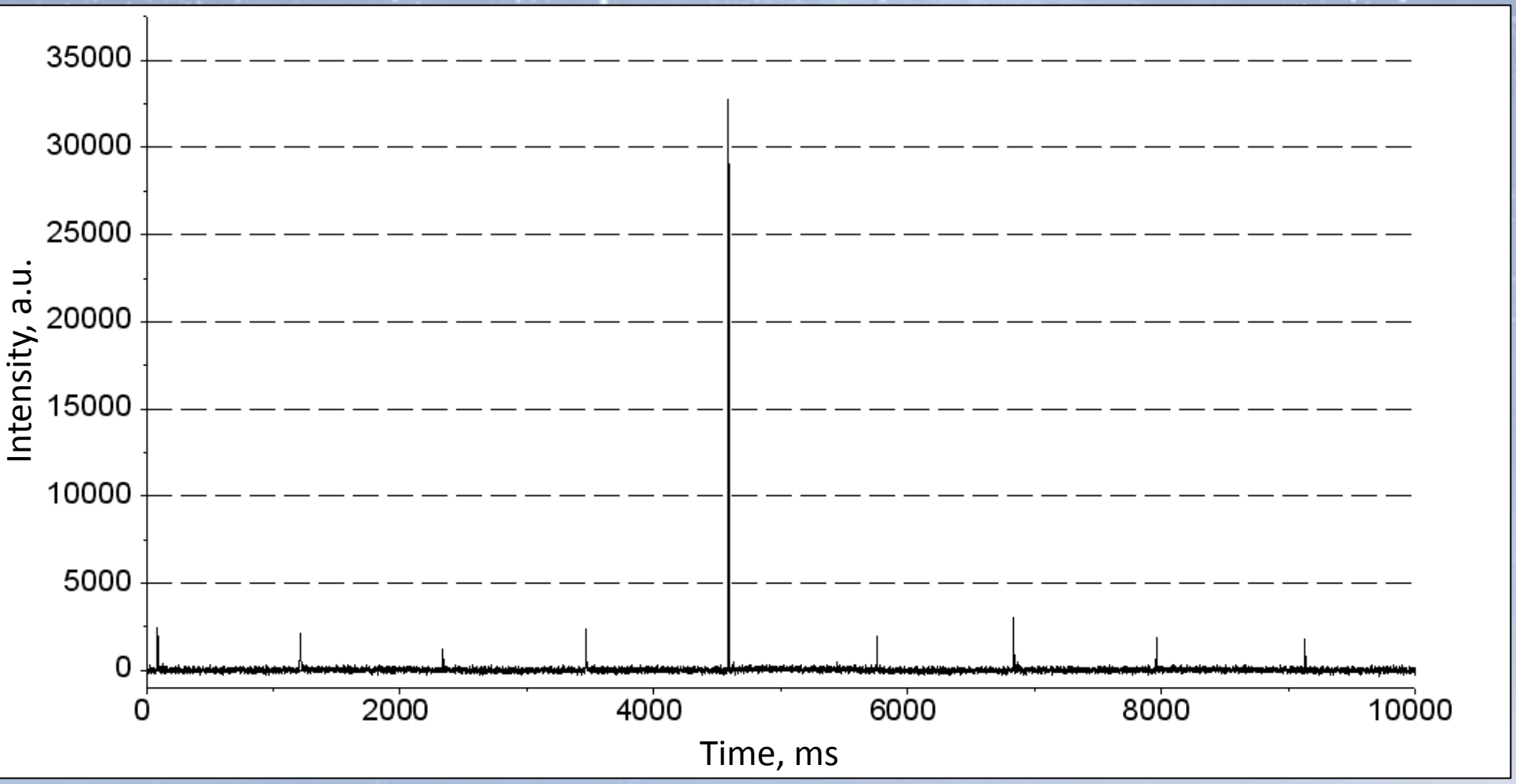


2695 МГц

(Hesse & Wielebinski) , 1974

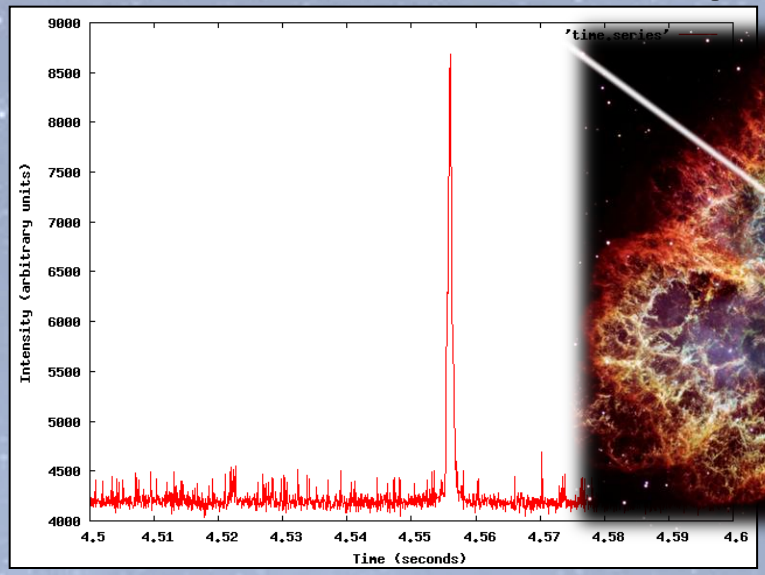
Excess of individual pulse's amplitude over amplitude of average profile typically can reach no more than ten times.

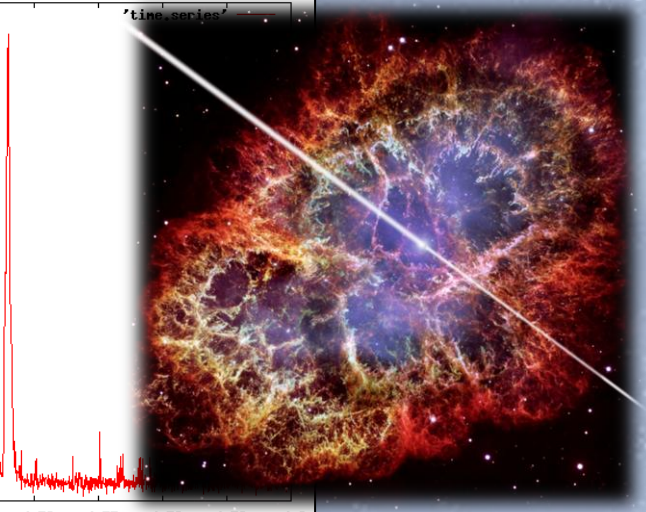
Giant pulses (GPs) of pulsar



Pulses that exceed the average profile over 30 times were called giant pulses.

First pulsars with GPs



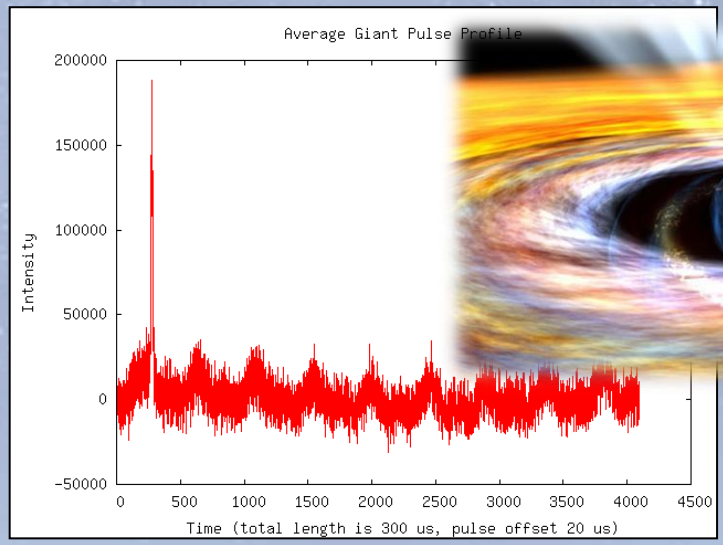


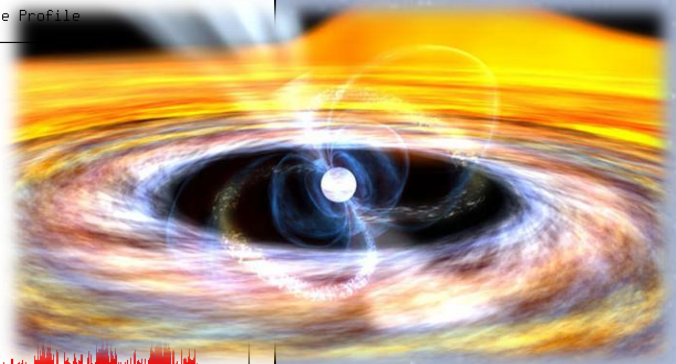
Crab (B0531+21)

P: 0.0331 s.

DM: 56.791 $cm^{-3}pc.$

Discovery: 1968.





B1937+21

P: 0.0016 s.

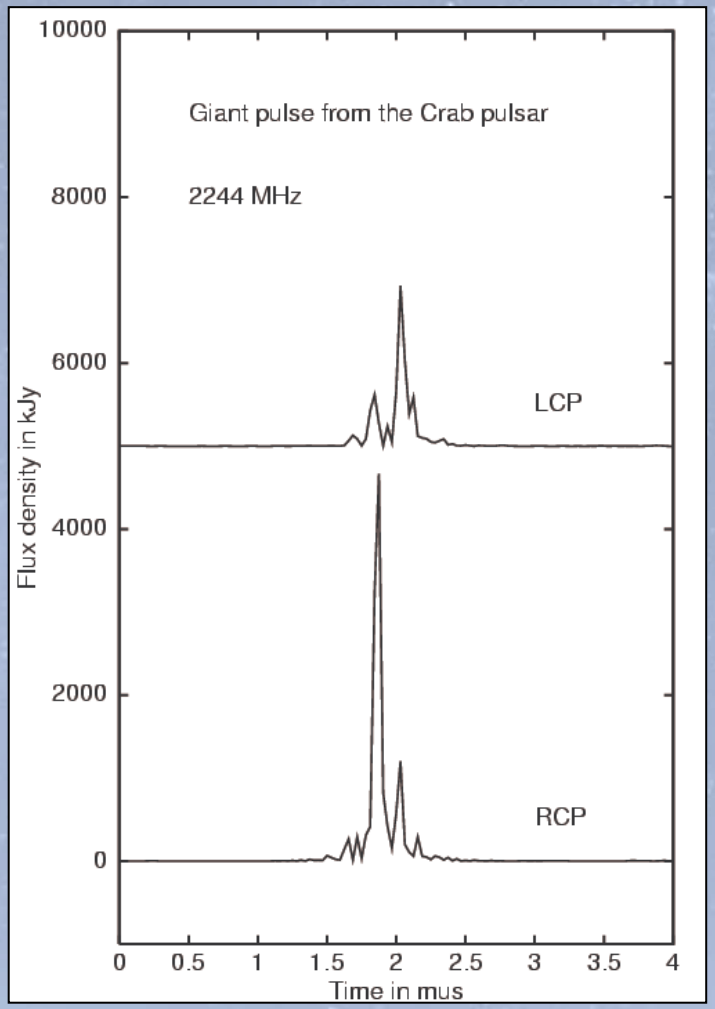
DM: 29.1168 $cm^{-3}pc.$

Discovery: 1984.

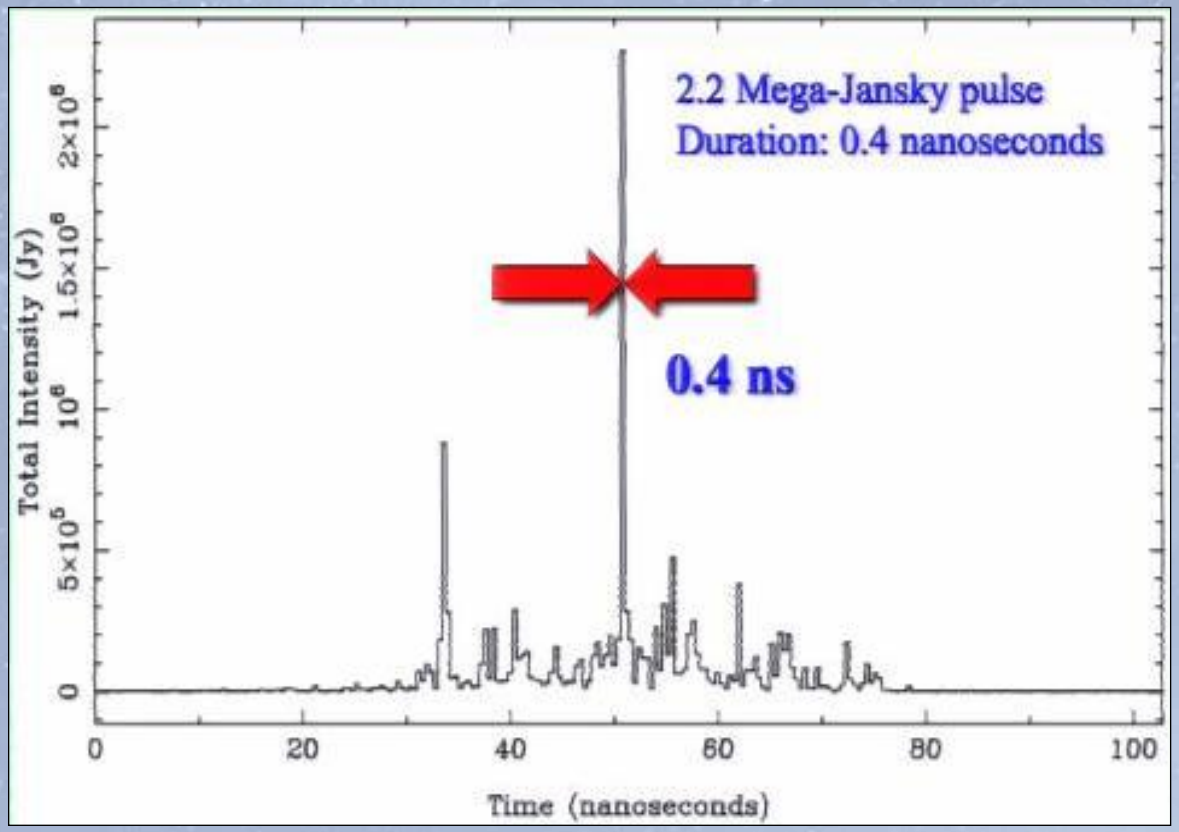
It should be noted that excess for these pulsars reach really giant values.

First pulsars with GPs

Pulsar in Crab nebulae (B0531+21) has most famous GPs.

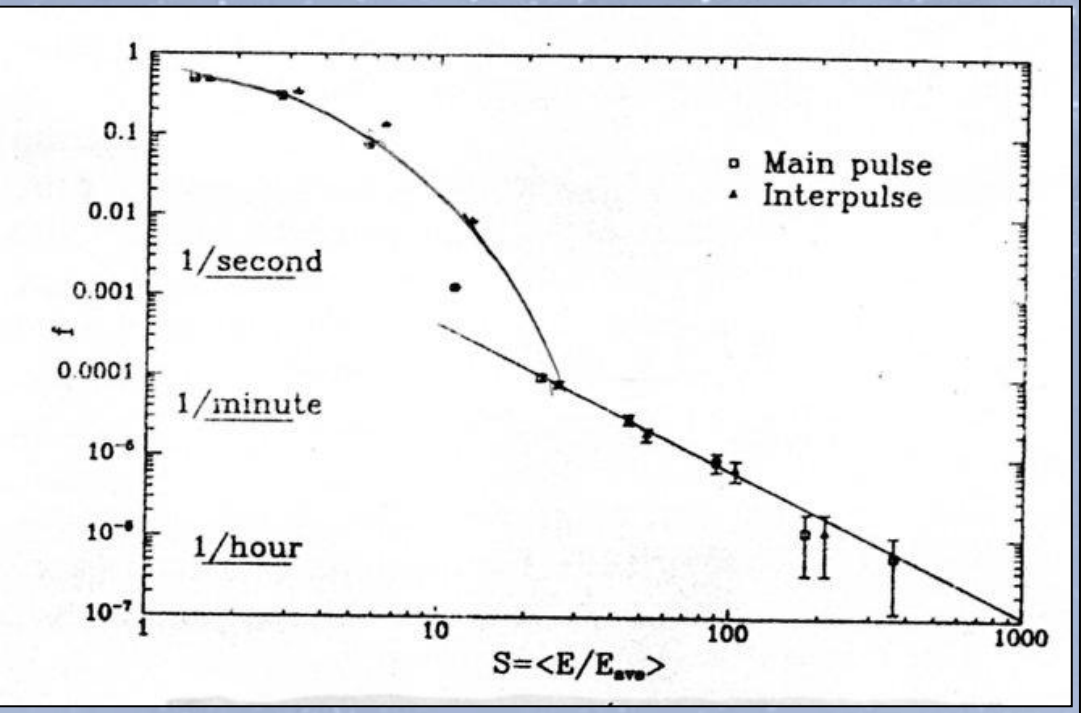


S ≈ 5 MJy
Kalyazin (Russia), 2005,
2244 MHz, B = 16 MHz
(Popov et al. 2005)



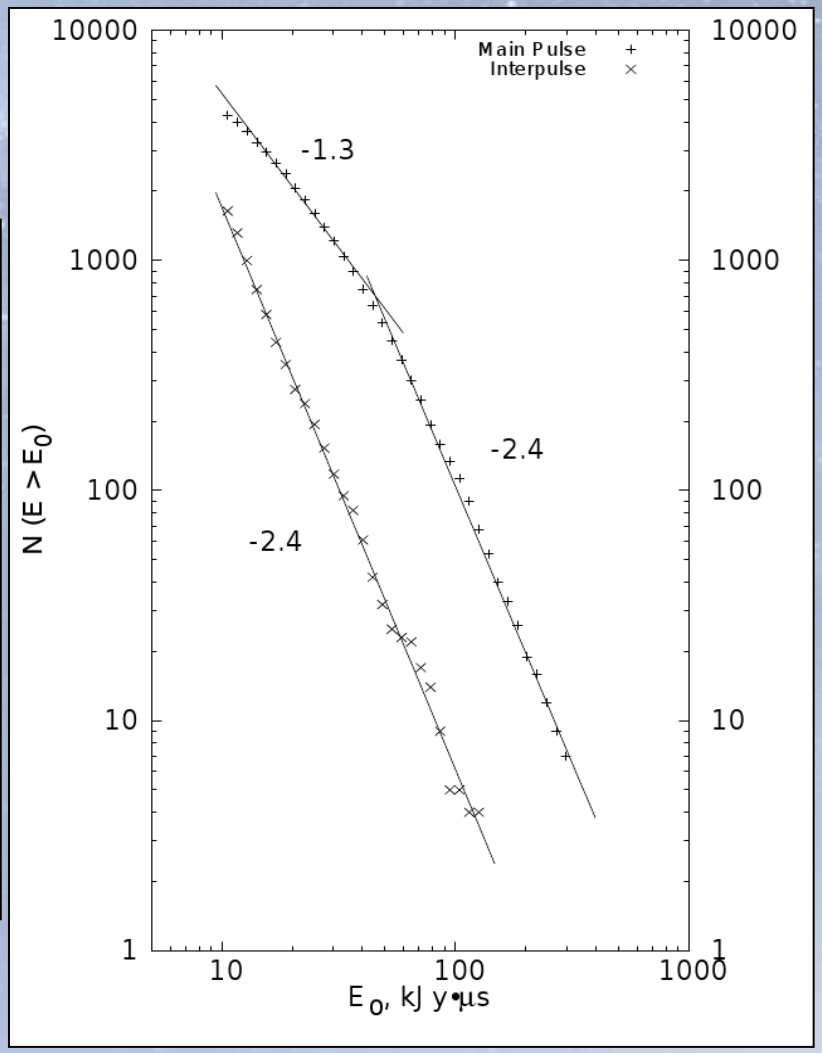
The shortest ever observed component of GRP of the Crab pulsar
(Hankins et al, 2003)

Individual pulses energy distribution



1937+21. Cognard et al. 1996

The kink in distribution is around 30 times of average flux density



0531+21. Popov et al., 2009

«Classical» properties of GPs

- Strong individual pulses tens, hundreds, thousands time as strong as averaged pulse.
- Peak flux density about hundreds, thousands and even millions Jy (when typical pulsar averaged pulse's flux is several Jy).
- Strong linear and circular polarization in pulse. E.g. ~60% GP of PSR B1937+21 are 100% circular polarized.
- GPs have a power law distribution both for peak flux and pulse's energy. Normal pulses have a Gaussian distribution on a logarithmic scale.
- GPs have short duration – up to several nanoseconds, e.g. B1937+21 *(Soglasnov et al, 2004)*
- GPs microstructure component may be as short as nanosecond or less, e.g. B0531+21 *(Hankins et al., 2003).*
- Extremely high brightness temperature:

B0531+21 $T_B \geq 5 \times 10^{37}$K;

B1937+21 $T_B \geq 5 \times 10^{39}$K

List of pulsars with GRPs (2015 г.)

Pulsar	P, s	P1, s/s	Frequency, MHz	DM, cm^{-3} pc	B_{LC}, G	First note
J0034-0721	0.9429	4.08e-16	40	11.380	7.02e+00	**2004**
J0218+4232	0.0023	7.73e-20	610	61.252	3.21e+05	**2004**
J0534+2200	0.0331	4.23e-13	40-8300	56.791	9.80e+05	**1968**
J0529-6652	1.0249	7.73e-11	610	103.20	3.97e+01	**2011**
J0540-6919	0.0505	4.79e-13	1390	146.500	3.62e+05	**2006**
J0659+1414	0.3849	5.50e-14	111	13.977	7.66e+02	**2003**
J0953+0755	0.2530	2.30e-16	111	2.958	1.41e+02	**2003**
J1115+5030	1.6564	2.49e-15	111	9.195	4.24e+00	**2003**
B1237+25	**1.38245**	**9.60e-16**	**111**	**9.242**	**4.14e+00**	**2014**
J1752+2359	0.4091	0.64e-15	111	36.000	7.11e+01	**2005**
J1824-2452A	0.0030	1.62e-18	1510	120.500	7.41e+05	**2001**
J1823-3021A	0.0054	3.38e-18	685	86.834	2.52e+05	**2005**
J1939+2134	0.0016	1.05e-19	111-5500	71.0398	1.02e+06	**1984**
J1959+2048	0.0016	1.69e-20	610	29.1168	3.76e+05	**2004**

The common physical model of the generation of the GPs is not available up to now.

Goal and tasks of research

- Goal:

  Search of the pulsar with GPs and investigation of their properties.

- Tasks:
  - monitoring of pulsars during several years,
  - search in the collected data pulses which satisfy the main characteristics of GPs (exceed the average profile over 30 times and power law distribution for peak flux and pulse's energy).

LPA of LPI radio telescope

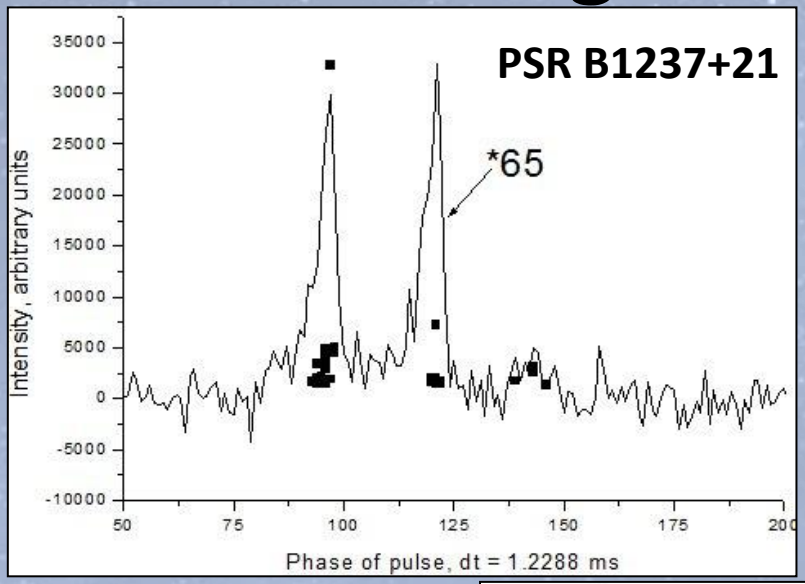
- Transit radio telescope. Phased array antenna. One linear polarization.
- Frequency: 111 MHz, Bandwidth: 2.3 MHz (460 x 5 kHz digital receiver with post-detector DM removal);
- Typical duration of one scan: 3 to 7 min. (e.g. B1237+21 - 3.53 min = 153 pulses);

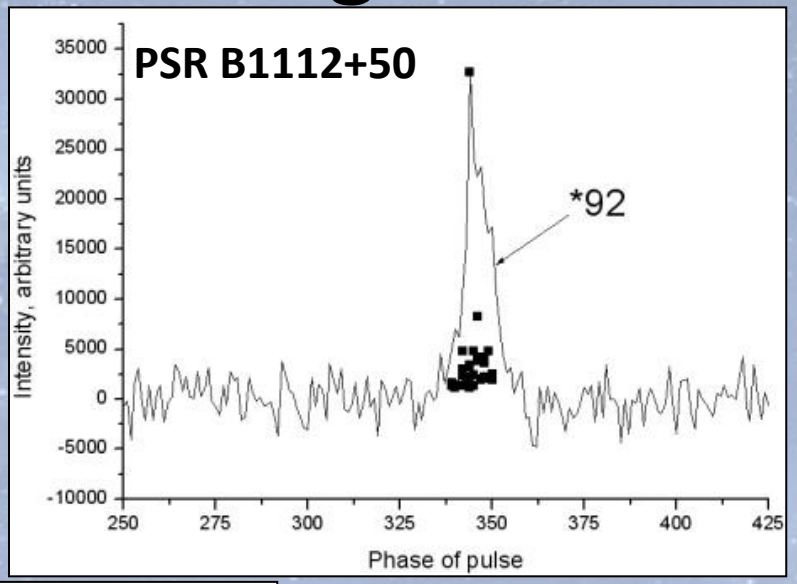
Objects of observations

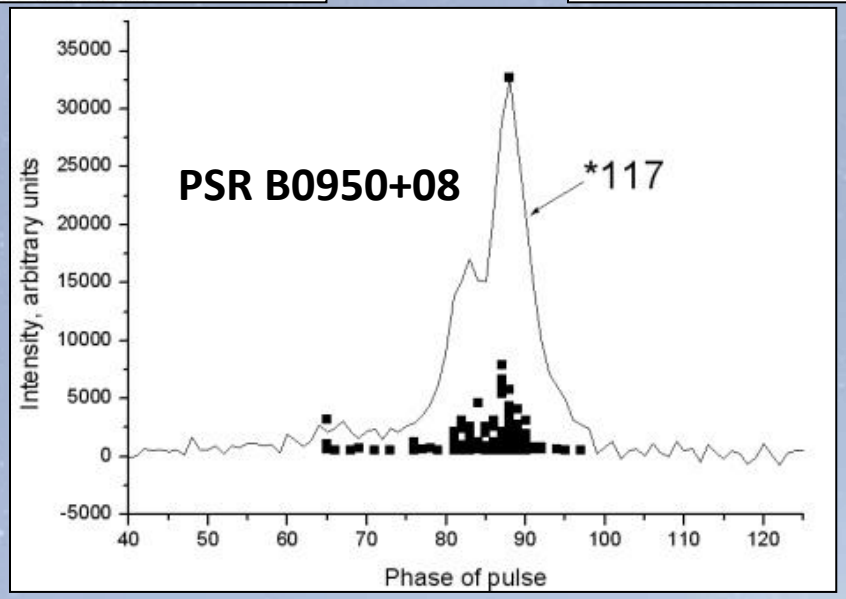
50 pulsars =
8 pulsars (monitoring) + 42 pulsars (search)

PSR B0007+73	PSR B0711+74	PSR B1534+12	PSR B1919+21	PSR B203 0+36
PSR B0218+42	PSR B0809+74	PSR B1541+09	PSR B1929+10	PSR B2032+41
PSR B0031-07	PSR B0823+26	PSR B1652+26	PSR *B1937+21*	PSR B2055+25
PSR B0301+19	PSR B0834+06	PSR B1737+13	PSR B1946+35	PSR B2110+27
PSR B0320+39	PSR B0919+06	PSR B1752+23	*PSR B1957+20*	PSR B2111+46
PSR B0357+32	*PSR B0950+08*	PSR B1828-10	PSR B1957+50	PSR B2139+47
PSR B0450+55	*PSR B1112+50*	PSR B1836+59	PSR B2016+28	PSR B2154+40
PSR B0622+37	PSR B1133+16	PSR B1839+09	PSR B2020+28	PSR B2217+47
PSR B0643+80	*PSR B1237+25*	PSR B1846+09	PSR B2021+40	PSR B2310+42
PSR B0656+14	PSR B1508+55	PSR B1855+09	PSR B2028+33	PSR B2315+21

Program of monitoring



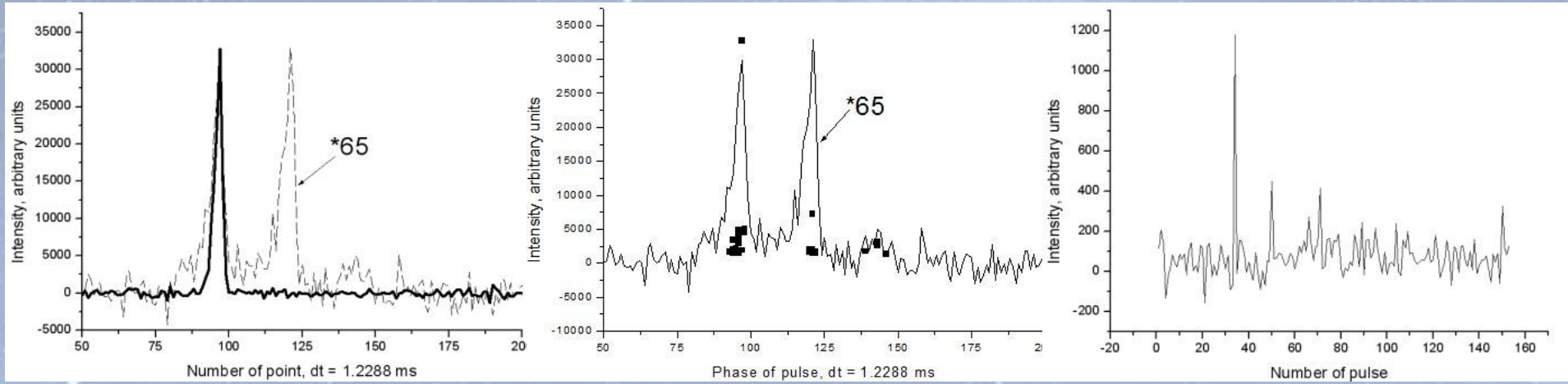




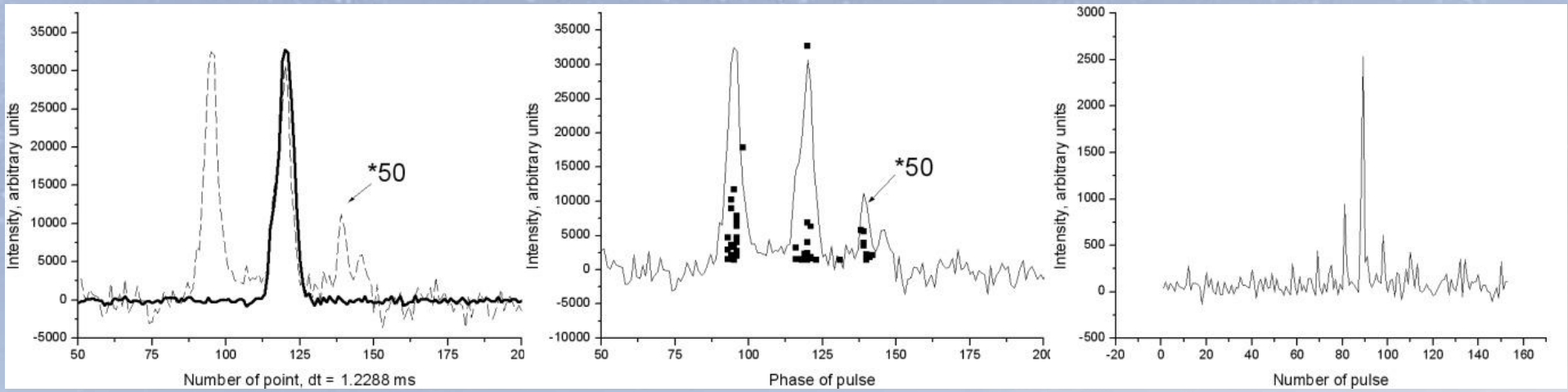
The monitoring program included pulsars which has been demonstrated GPs generation phenomenon previously

Discovery of GPs of B1237+25

GPs from B1237+25 were discovered in 2014 by our group.



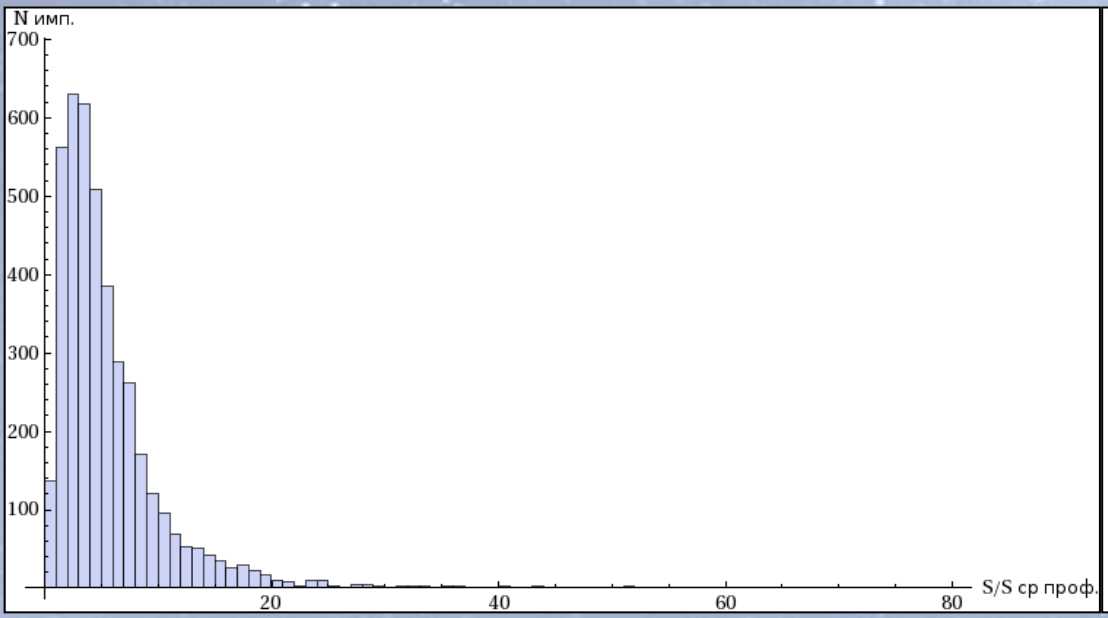
This phenomenon can be detected in all components of average profile.



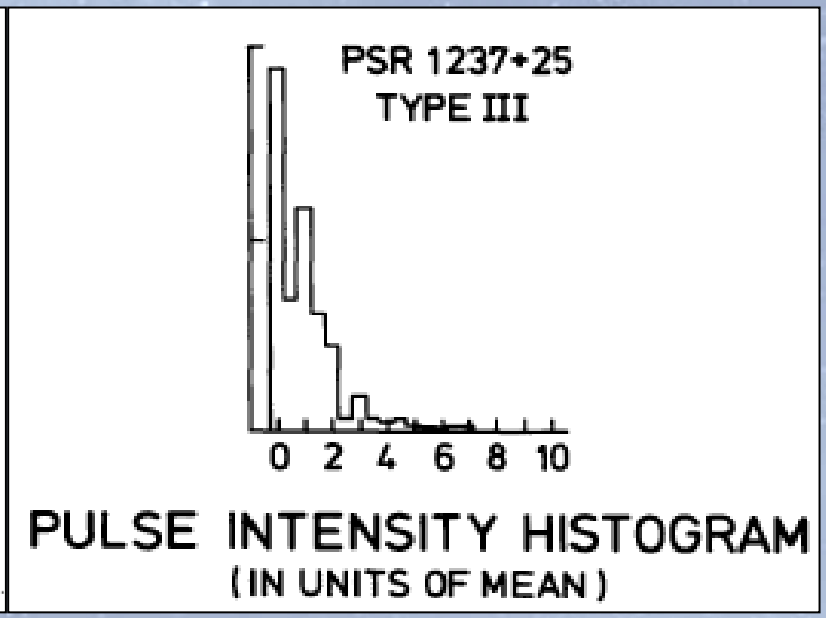
(*Kazantsev & Potapov, Astr.Tsirk., No.1620, 2015*)

$f_a = 15/10000$

Individual pulses histograms for B1237+25



111 MHz



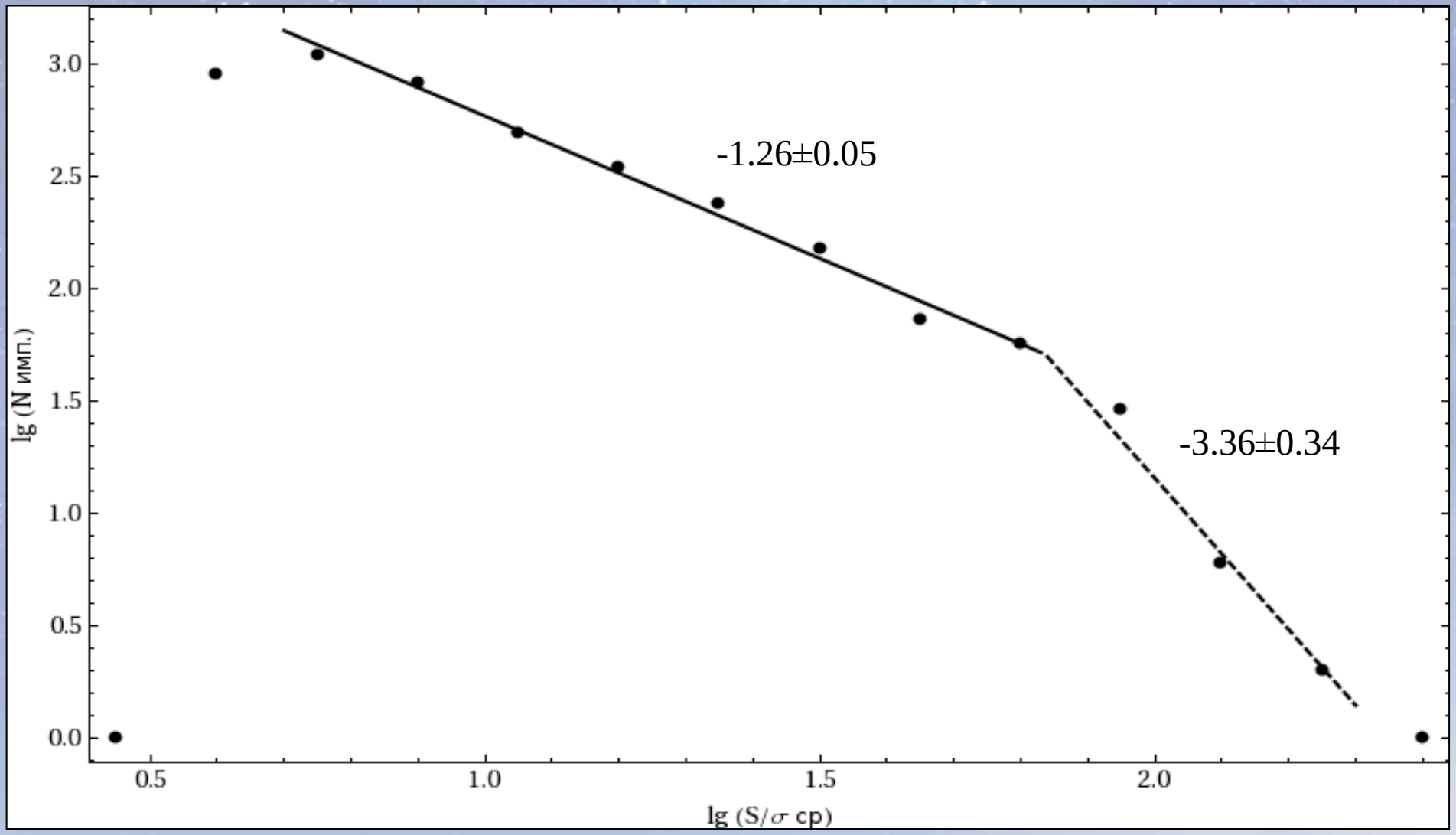
2695 MHz

K.H. Hesse & R. Wielebinski, 1974

Differs for histogram at 2695 MHz (no subpeaks). Much stronger in maximum

GPs peak flux distribution (B1237+25)

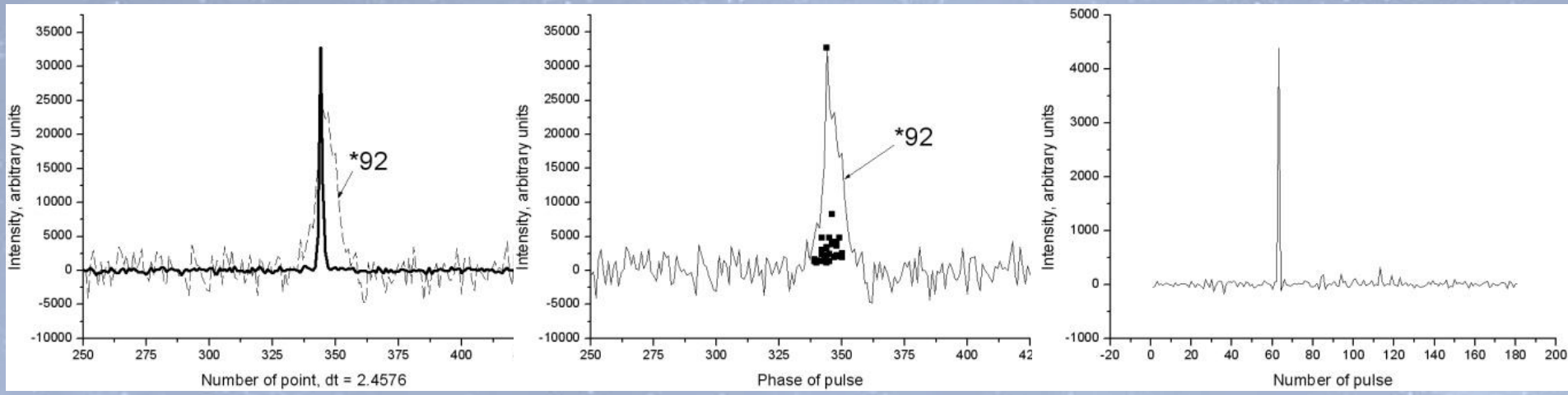
Strongest GRP: S_{max} = 900±200 Jy.



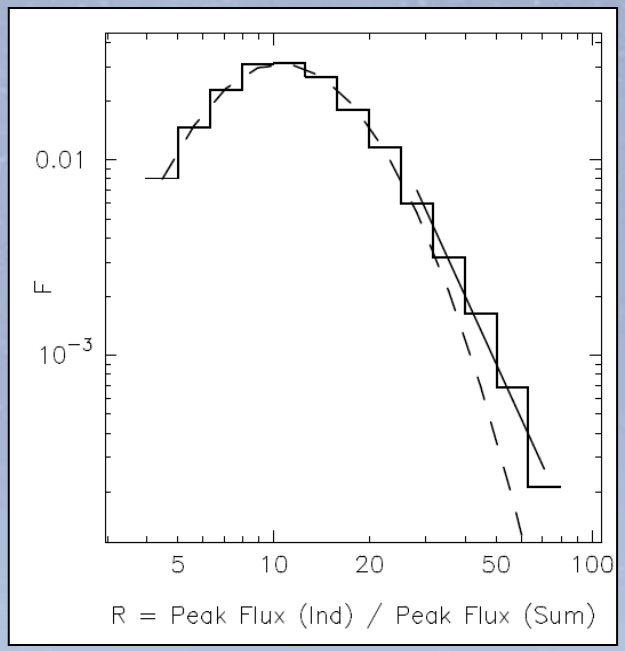
(*Kazantsev & Potapov, 2015*)

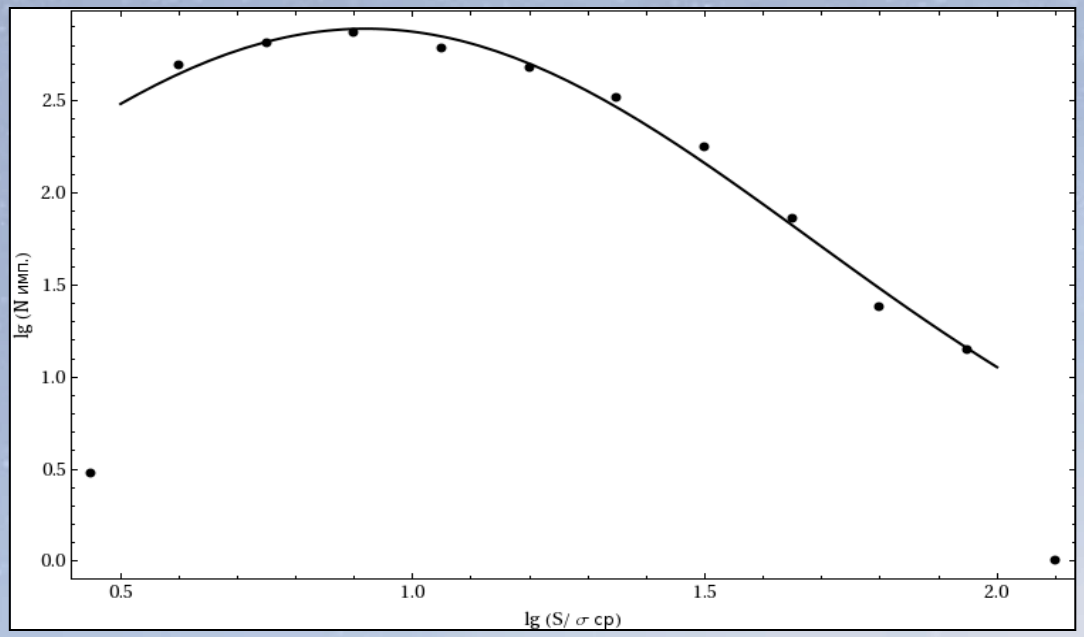
GPs B1112+50 monitoring

GPs from B1112+50 were discovered by Ershov&Kuzmin in 2003



GPs of B1112+50 distributions



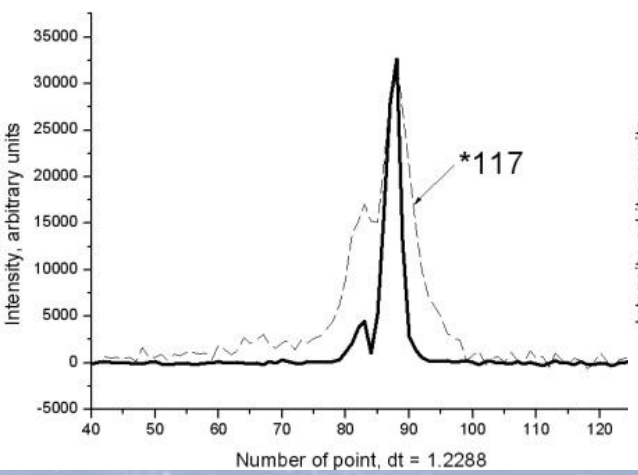


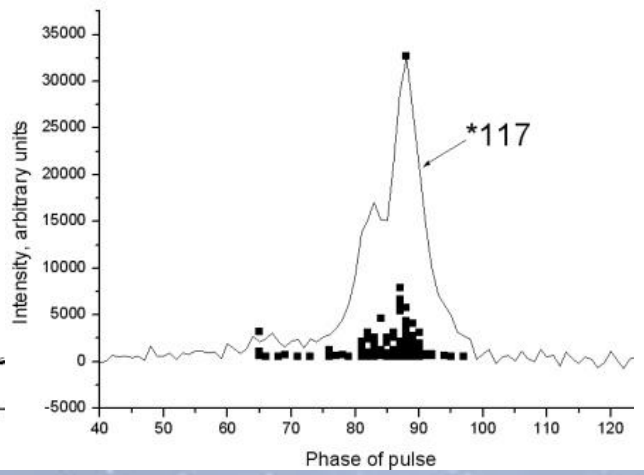
Ershov, Kuzmin, 2003

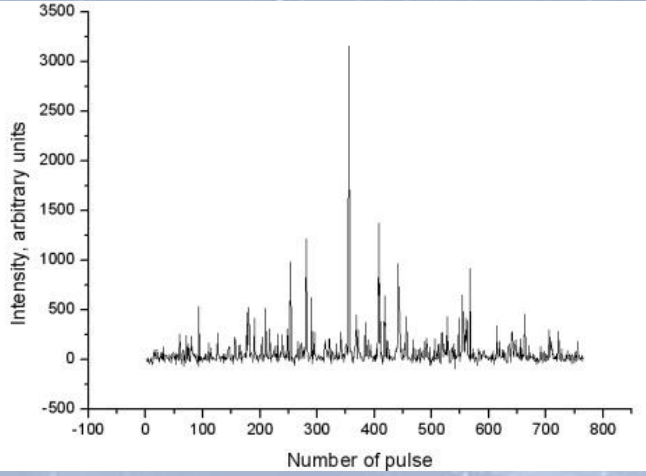
Kazantsev, Potapov, 2013

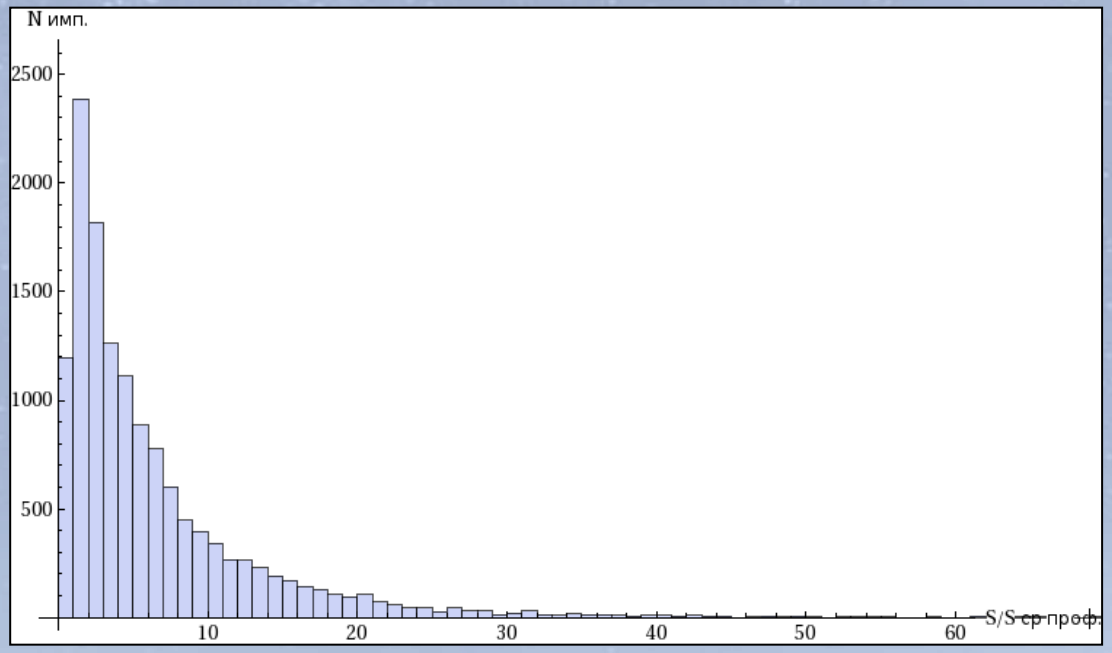
GRPs B0950+08 monitoring

GPs from B0950+08 were discovered by A.K. Singal // Astrophysics and Space Science, 2001, V.278, P.61

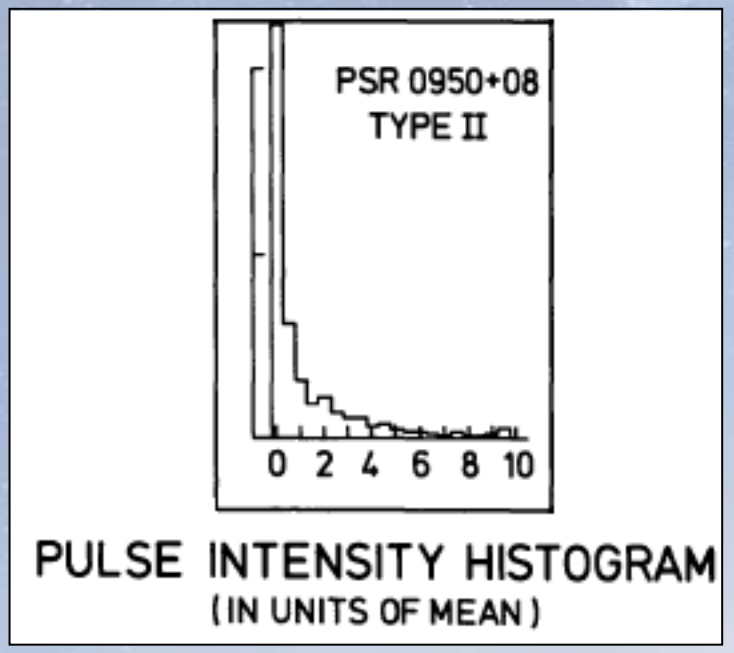






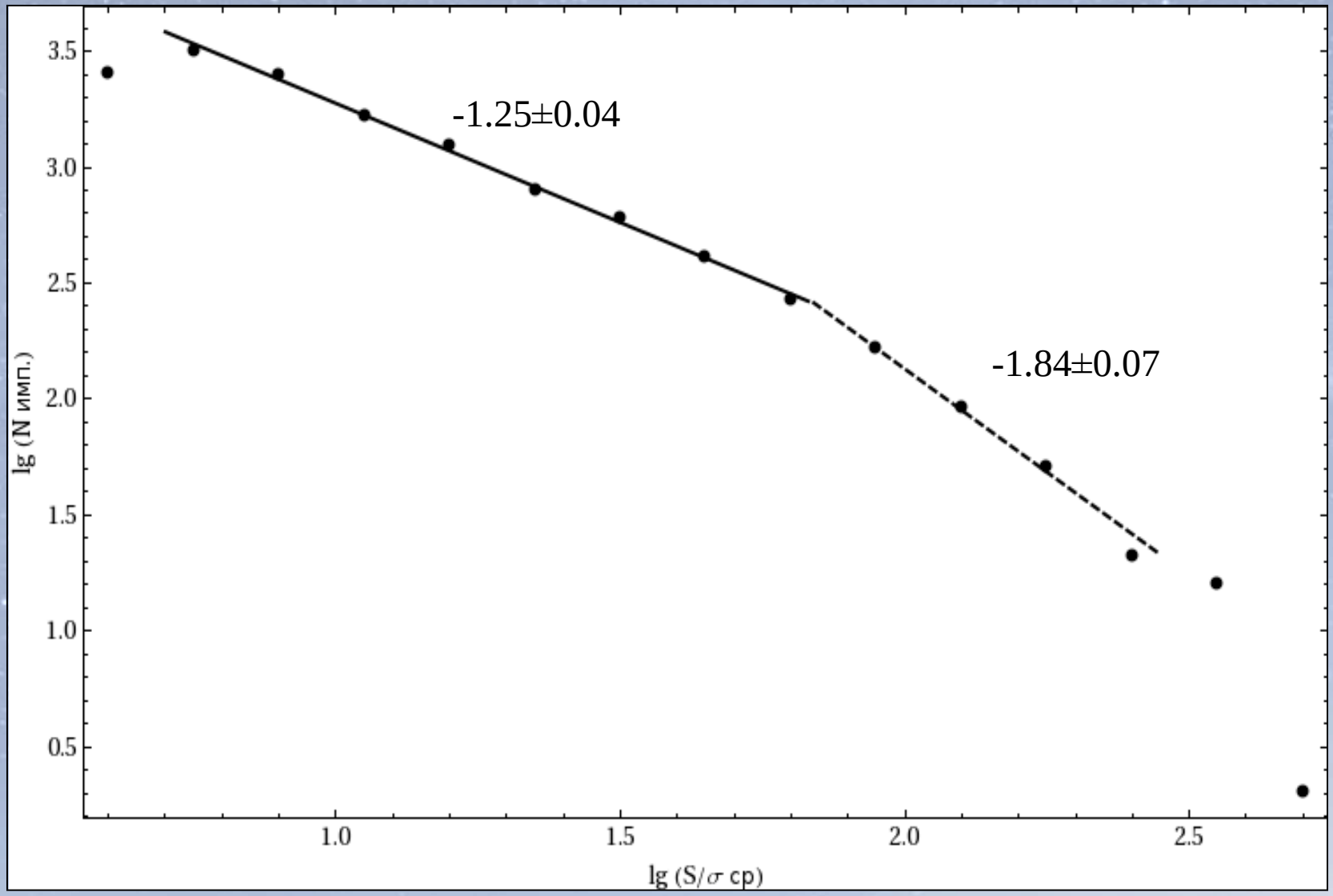


111 MHz



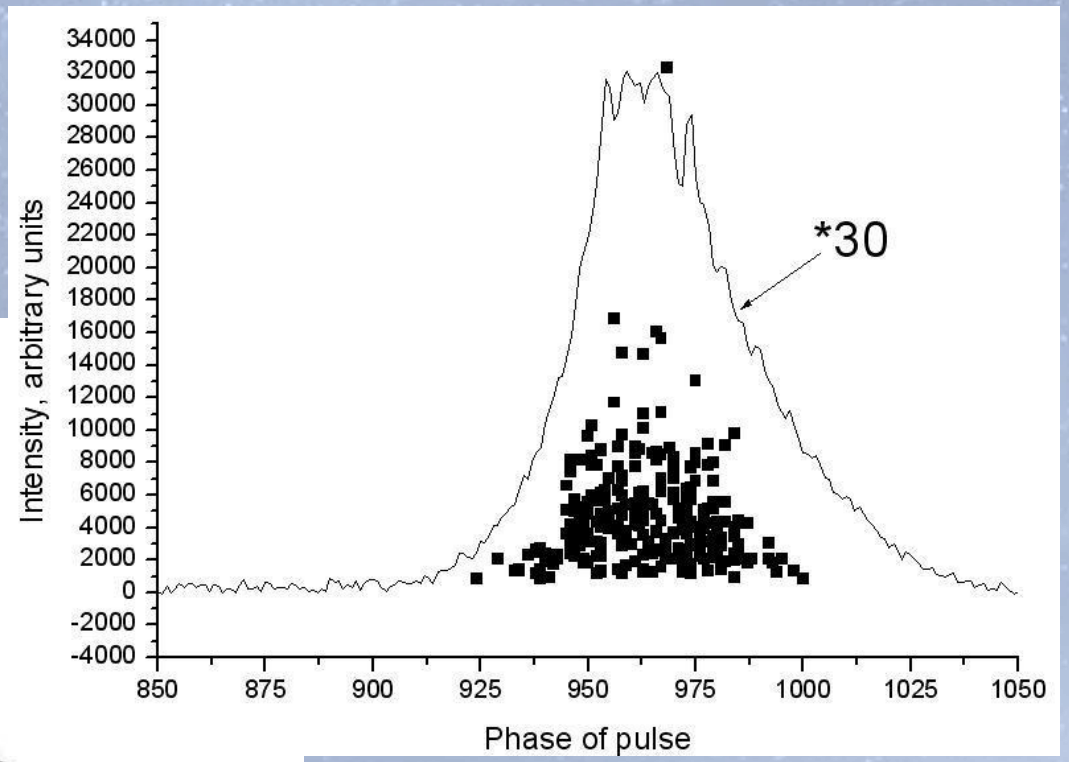
2695 MHz

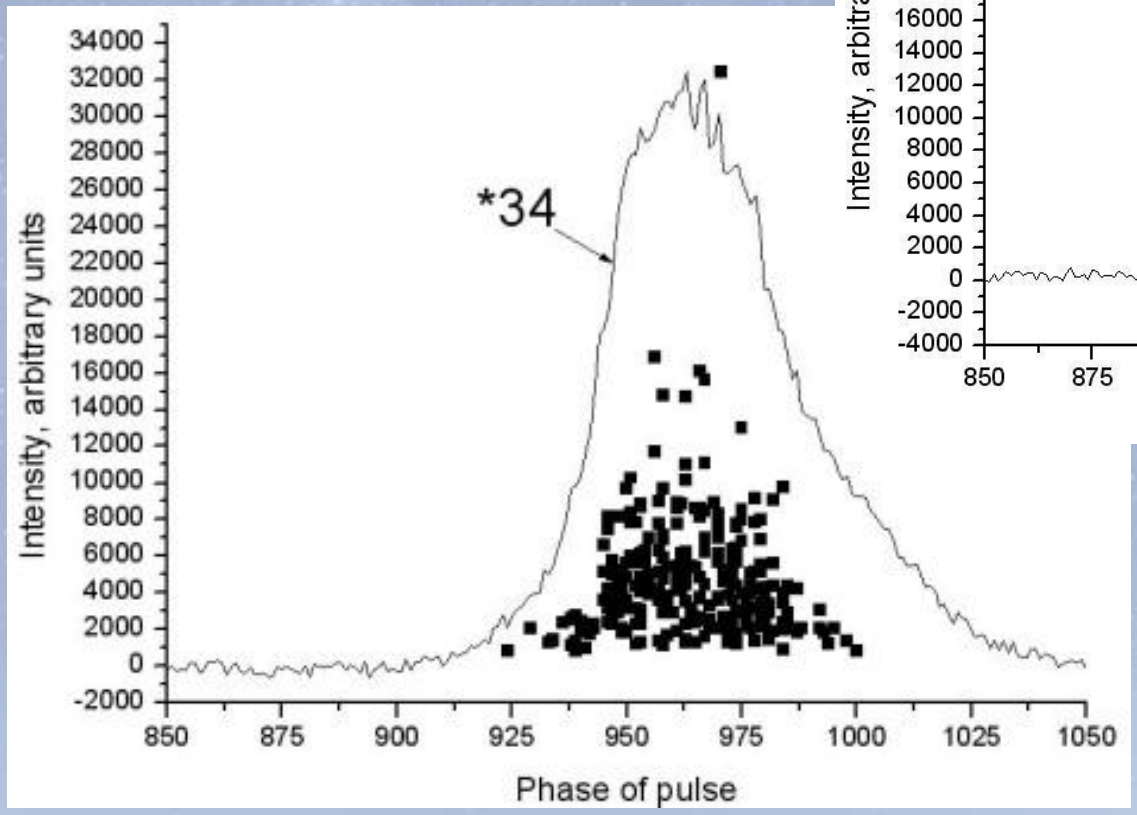
GPs peak flux distribution (B0950+08)



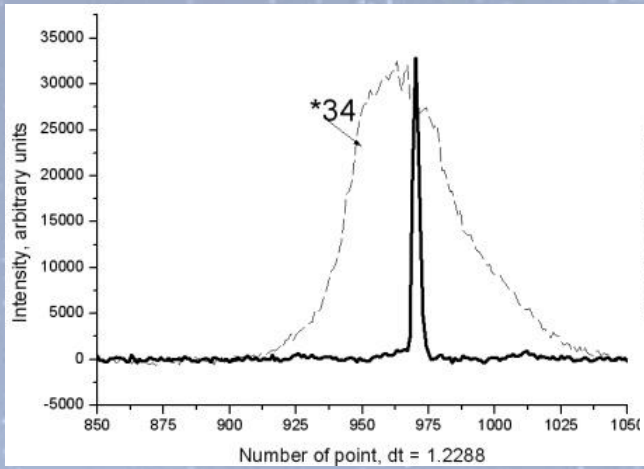
Results are consistent with early obtained at 111 MHz (Smirnova, 2012)

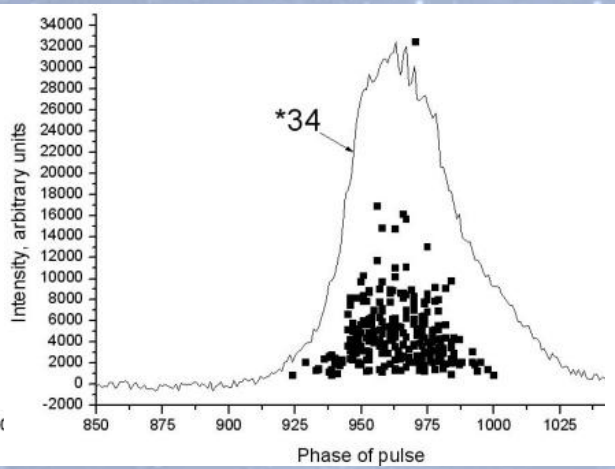
Individual pulses of B0809+74

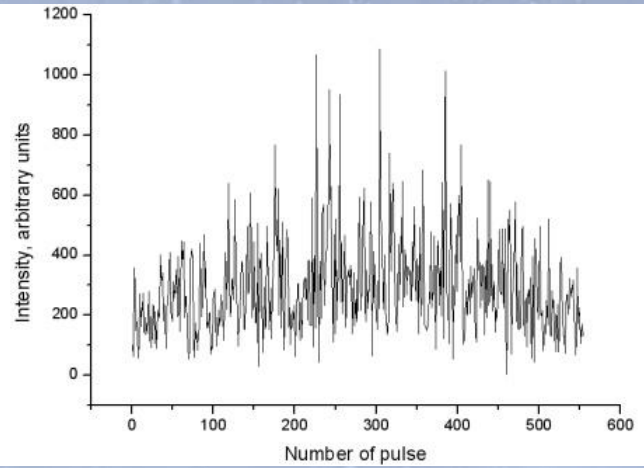




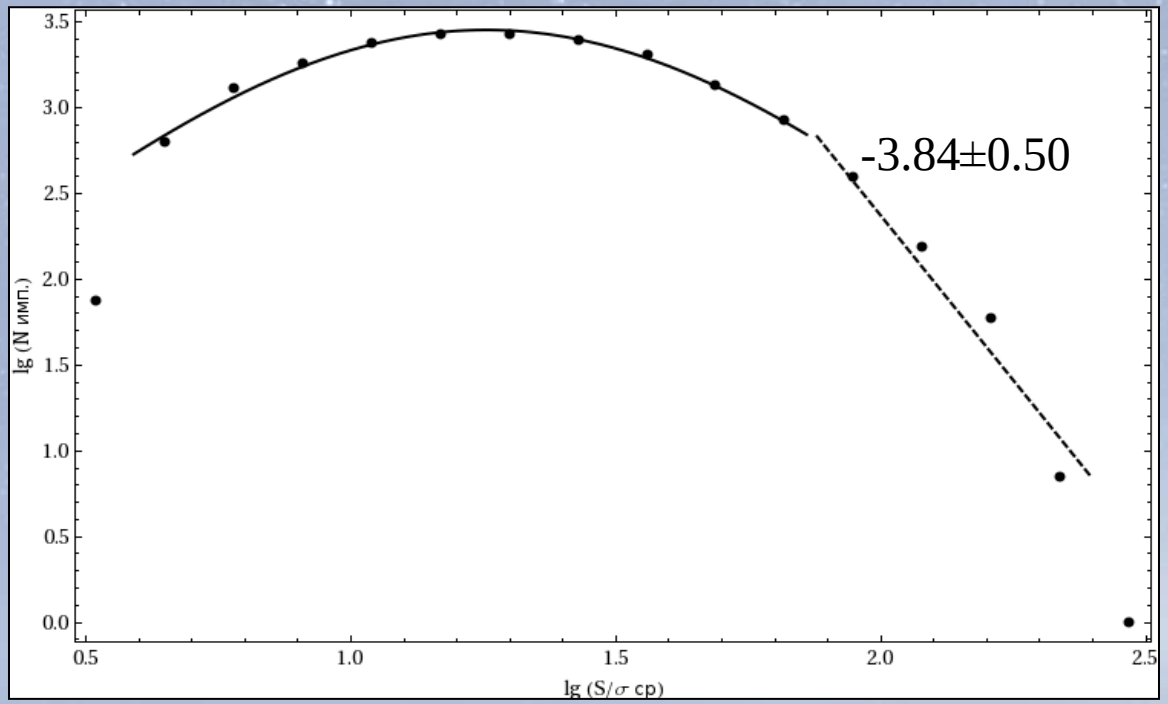
Energy distribution for B0809+74





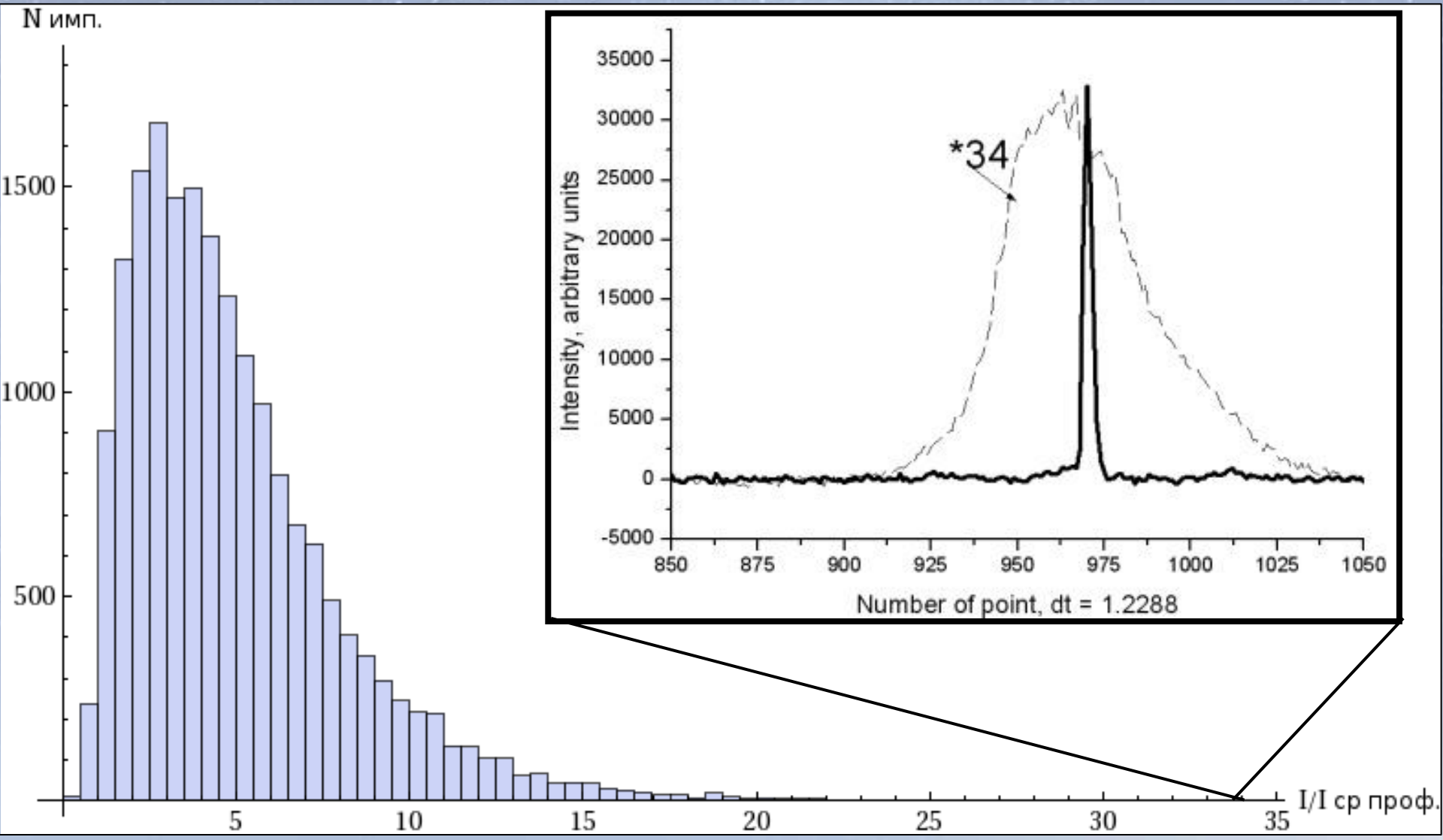


Individual pulses' peak flux distribution

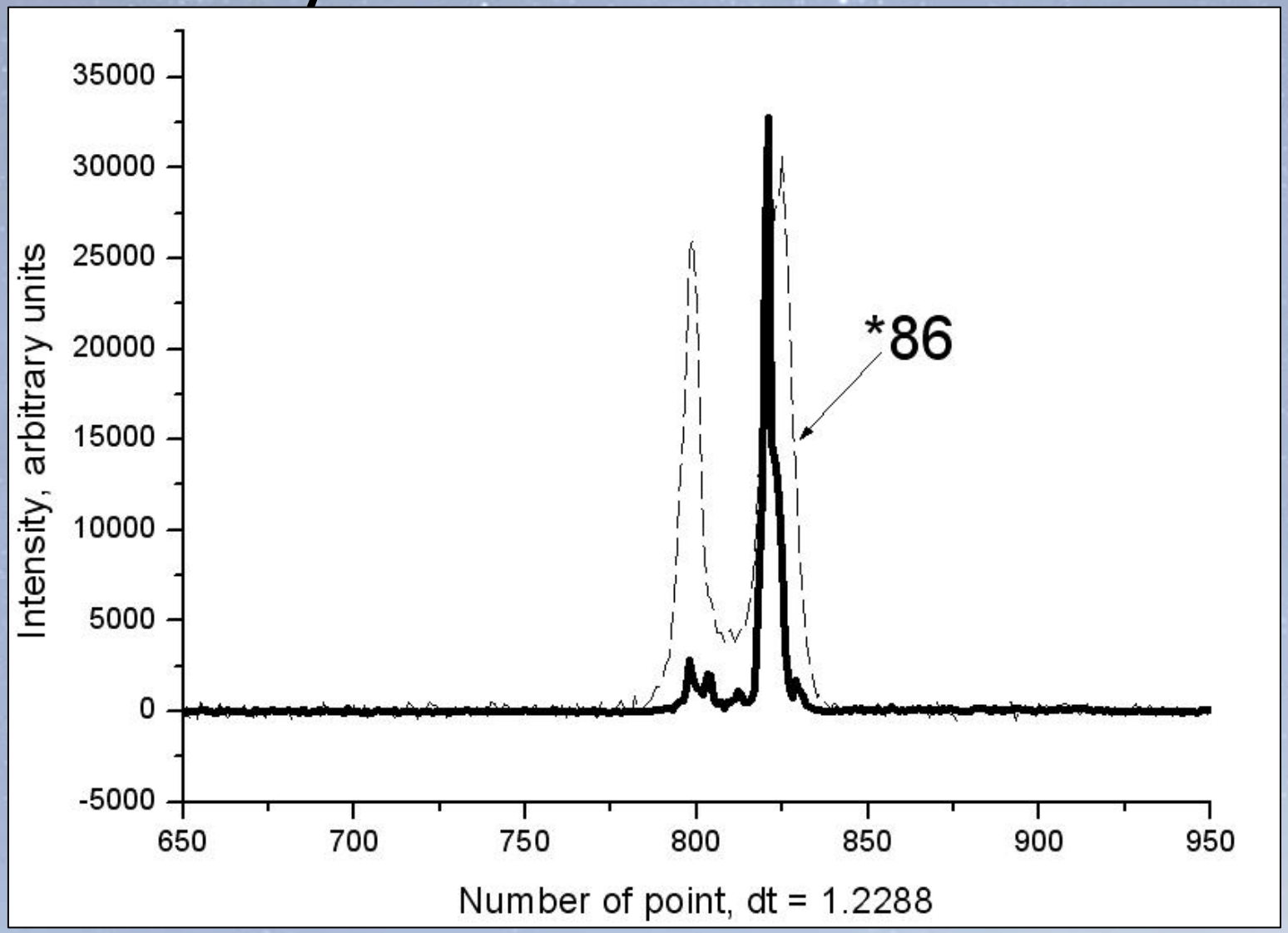


Strong individual pulses of B0809+74

Now it is a candidate only.

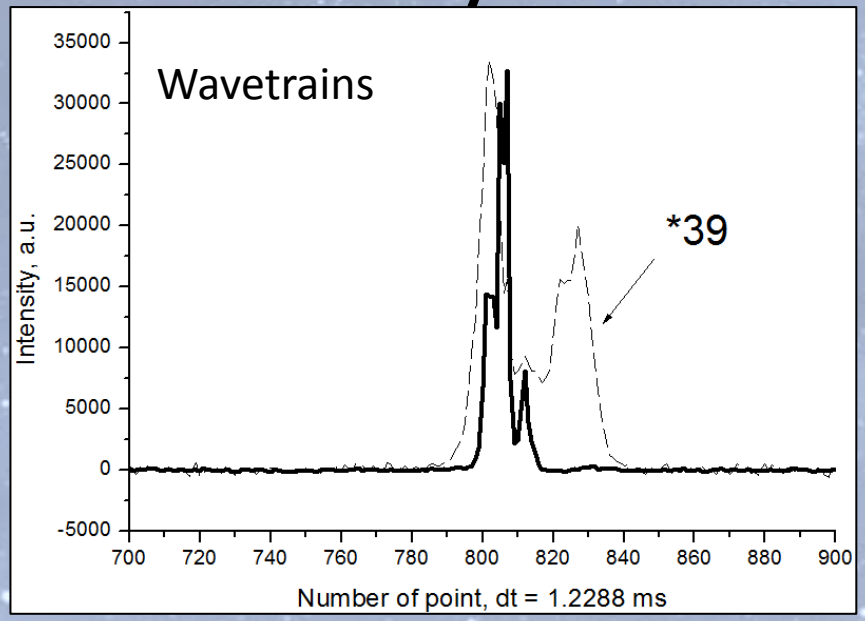


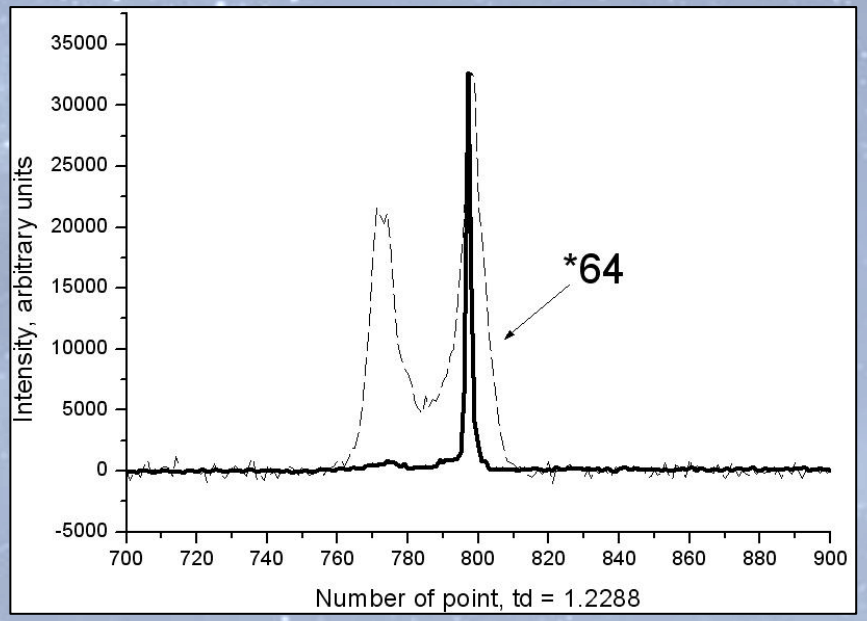
Discovery of GPs from PSR B1133+16

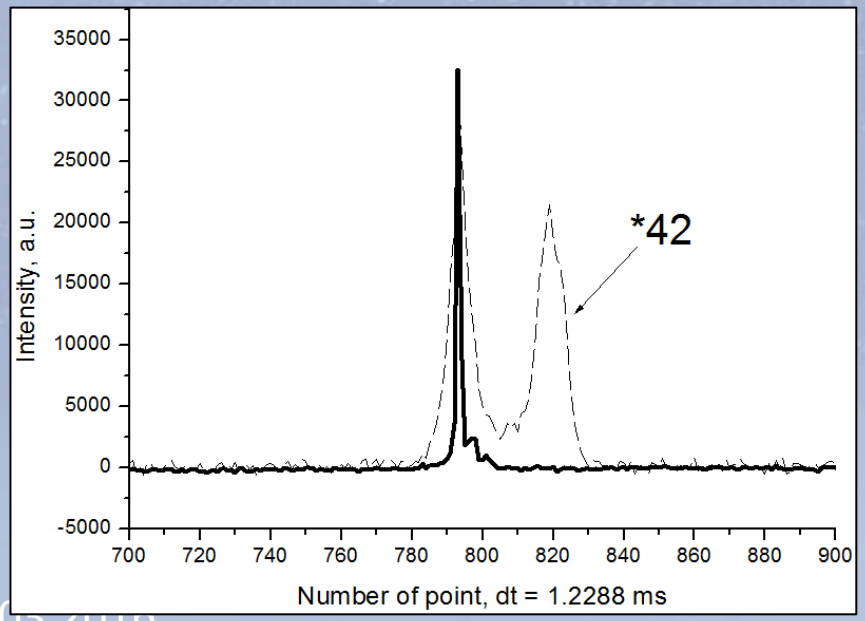


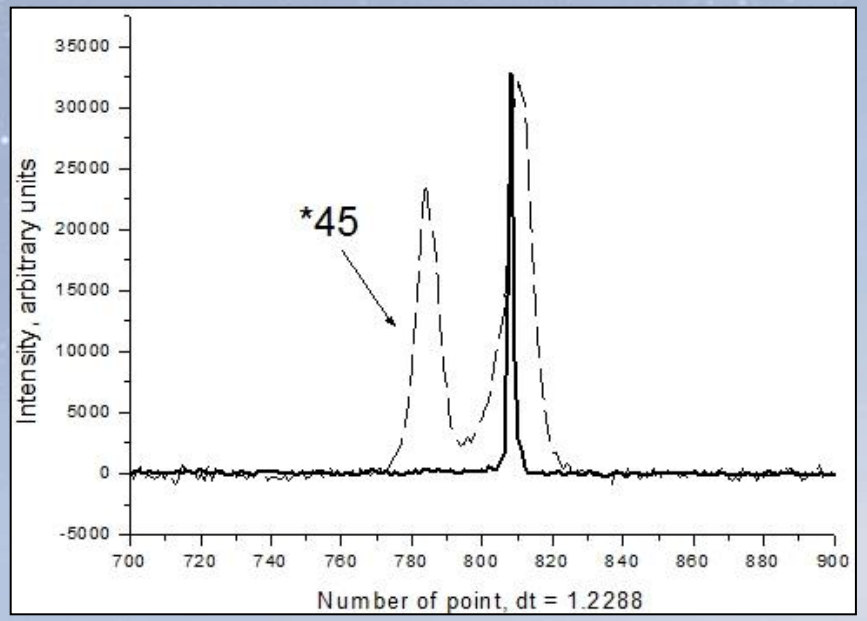
$f_a = 1/1000$

Discovery of GPs from PSR B1133+16

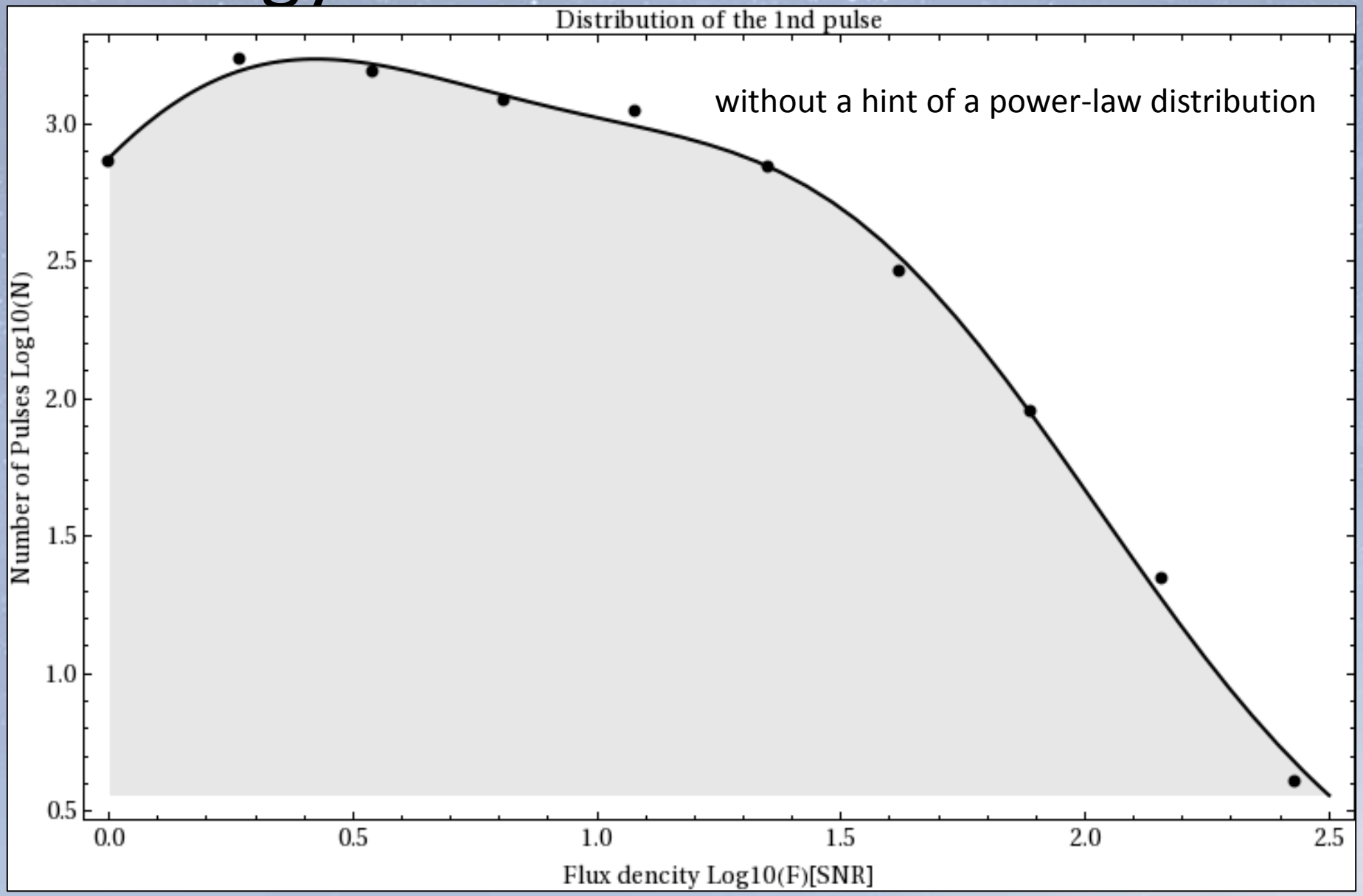




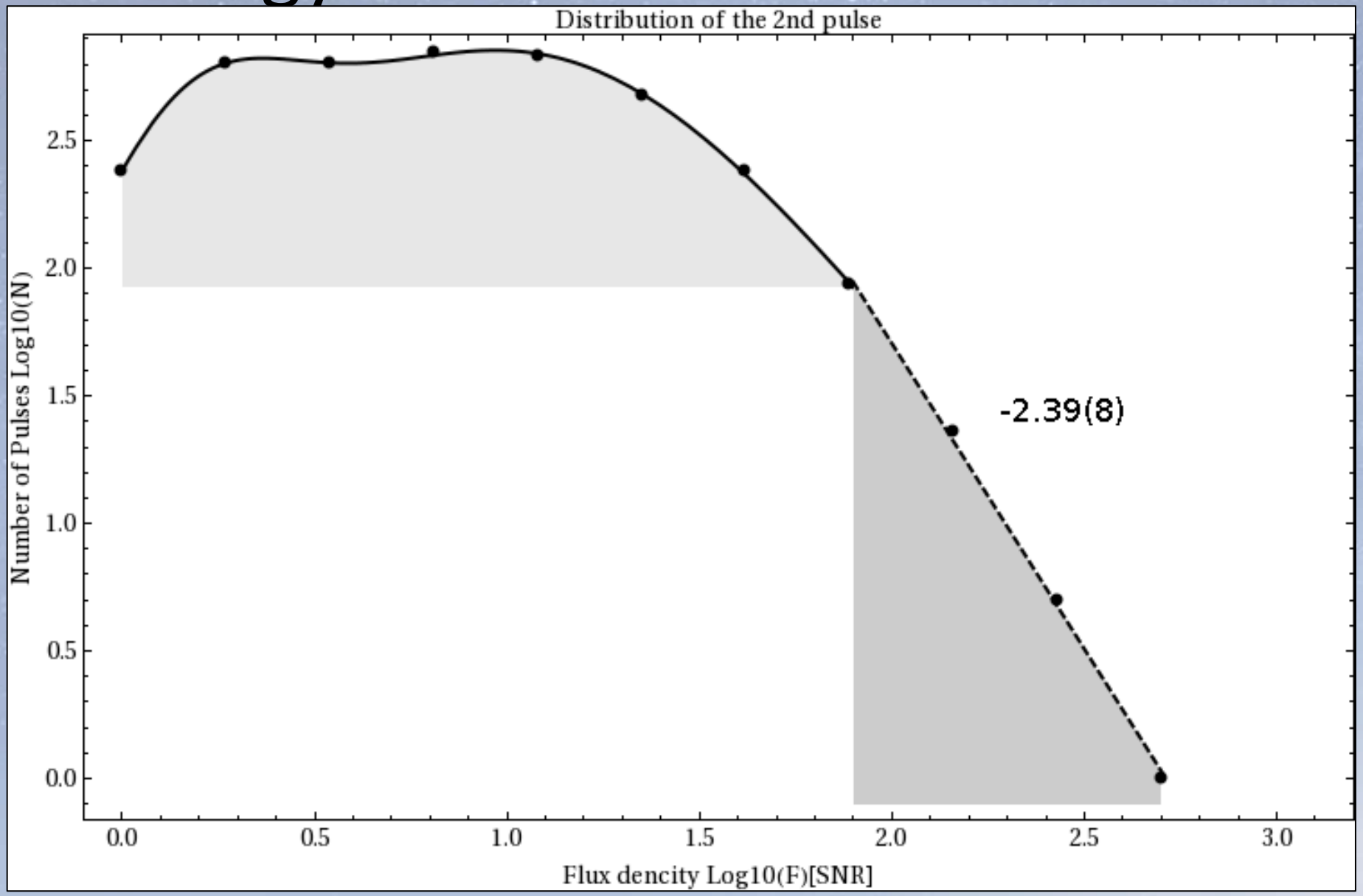




Energy distribution for B1133+16



Energy distribution for B1133+16



Conclusions

- Longtime observation program for monitoring and search GPs is conducted.
- Strong individual pulses with some properties of GPs were detected from B0809+74 (more observations need).
- GPs were discovered from B1133+16 and B1237+25
- There were confirmed regular GPs for 2 of 5 pulsar that was found earlier at low frequency (102-111 MHz)
- We can conclude that the phenomenon of GP may be quite distributed in low radio frequencies (about 10% from our observation list) but criteria of GPs are less defined and obvious than that of 2 “classical” pulsars with GPs.

THANK for YOUR attention