• Giant Pulses of Pulsar Radio Emission

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- **Isolated Neutron Stars:**
- **from the Interior to the Surface, B9**
- **London 2006**

Giant pulses (GPs)- a short duration outbursts-
are a special form of pulsar radio emission.

GPs is the most striking phenomena of pulsars radio emission.
Their flux densities can exceed hundreds and thousands of times
the mean flux density of regular pulses from the pulsar.

GPs from the millisecond pulsar B1937+21
have been observed as strong as corresponding
to a brightness temperature of $T_B \geq 5x10^{39}$ K,
the highest observed in the Universe (Soglasnov et al. 2003).

This rare event was observed only in 11 pulsars among more than 1500 known ones.

History and Dynamic of GPs Detection

First steps - accidental detections

PSR B0531+21	Staelin & Refenstein	1968
PSR B1937+21	Wolszczan et al.	1984

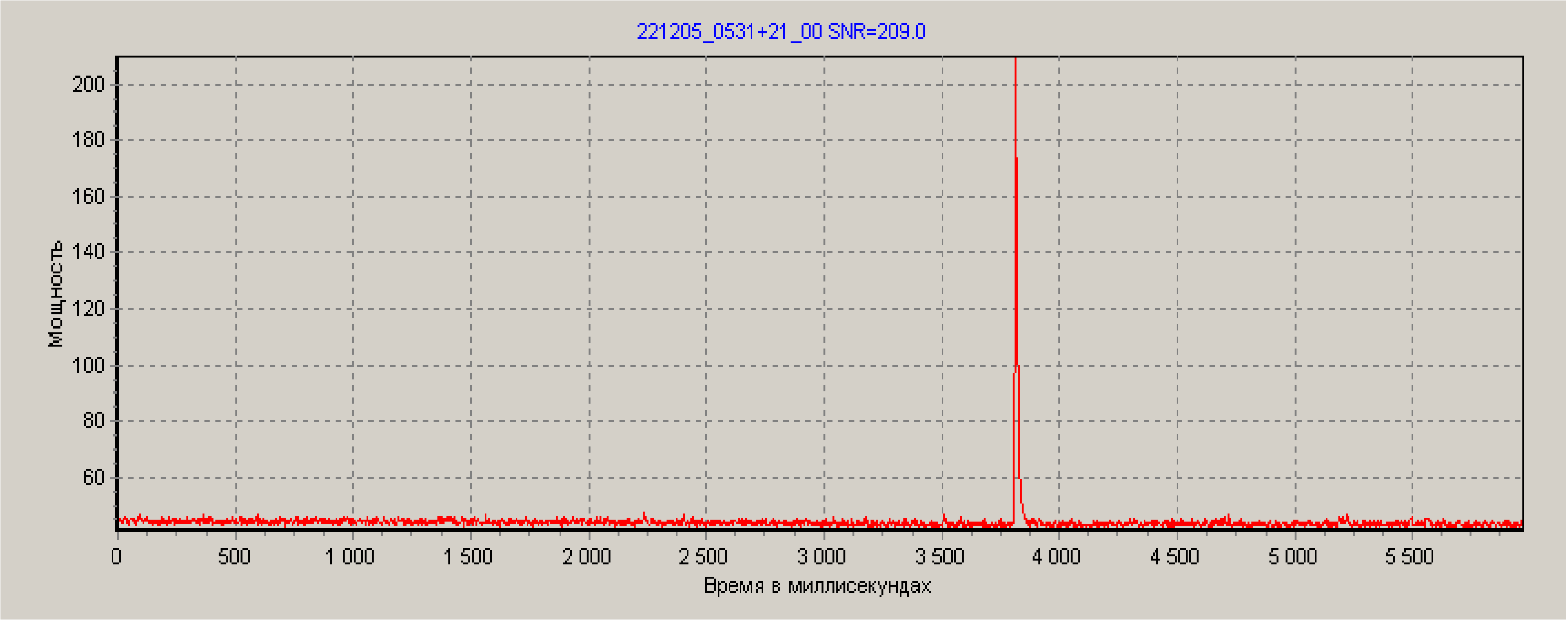
Systematic search - Fast progress

PSR B1821-24	Romani & Johnston	2001
PSR B1112+50	Ershov &Kuzmin	2003
PSR B0540-69	Johnston & Romani	2003
PSR B0031-07	Kuzmin & Ershov et al.	2004
PSR J0218+42	Joshi et al.	2004
PSR B1957+20	Joshi et al.	2004
PSR J1752+2359	Ershov & Kuzmin	2005
PSR J1823-3021A	Knight, Bailes et al.	2005
PSR B0656+14	Kuzmin & Ershov	2006

Giant pulses (GPs) of pulsars are distinguished by several special properties:

3. The peak flux and energies of GPs greatly exceed the peak flux and energy of the regular pulses.

An example of a GP of the Crab pulsar



Giant pulse stands out of the noise background and weak regular pulses observed inside of 180 pulsar periods.

- 2. Giant pulses are very short and bright:
- Soglasnov et al. (2004) have proved that majority giant pulses
- from the millisecond pulsar B1937+21 are shorter than 15 ns;

Hankins et al. (2003) found Crab pulsar pulse structure as short as 2 ns.

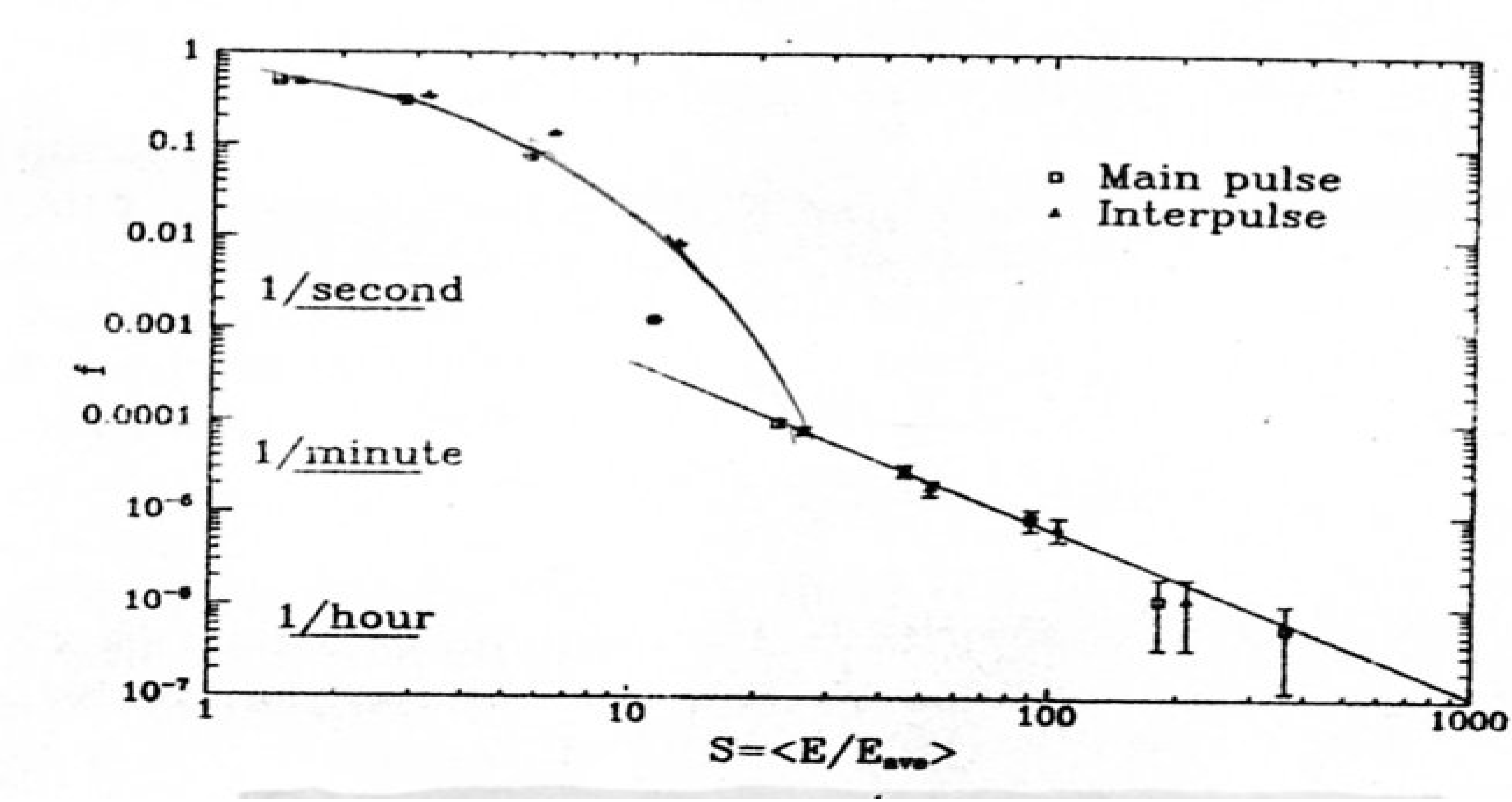
- If one interprets the pulse duration in terms
- of the maximum possible size of emitting region, then
- 2 ns corresponds to a size of emitting body of only 60 cm,
- the smallest entity ever detected outside our solar system.

- A brightness temperature of GPs are
- $T_B \geq 5 \times 10^{37}$K,
- for Crab pulsar B0531+21 (Hankins et al 2003)

- and $T_B \geq 5 \times 10^{39}$ K,
- for B1937+21 (Soglasnov et al 2004)
- the highest observed in the Universe.

•3. An intensity distribution of GPs has a power-law.

Cumulative distribution of the pulse energy of pulsar PSR B1937+21 relative to the mean regular pulse energy (Cognard et al. 1996)



For giant pulses with E/E_{mean} >20 the distribution has roughly a power-law. For lower intensities regular pulses distribution is Gausian.

These two pulsars share the common property of
the extremely high magnetic field at the light cylinder

PSR	0531+21	B1937-24
B_{LC}, G	9.3E5	9.8E5

Therefore, it was suggested that the giant pulses radio emission may depends on conditions at the light cylinder, rather than close to the stellar surface. The first searches of GPs were performed in pulsars with extremely high magnetic field at the light cylinder.
Five more such pulsars with GPs PSR B1821-24, B1957+20, B0540-69, J0218+4332, J1823-3021A were detected.

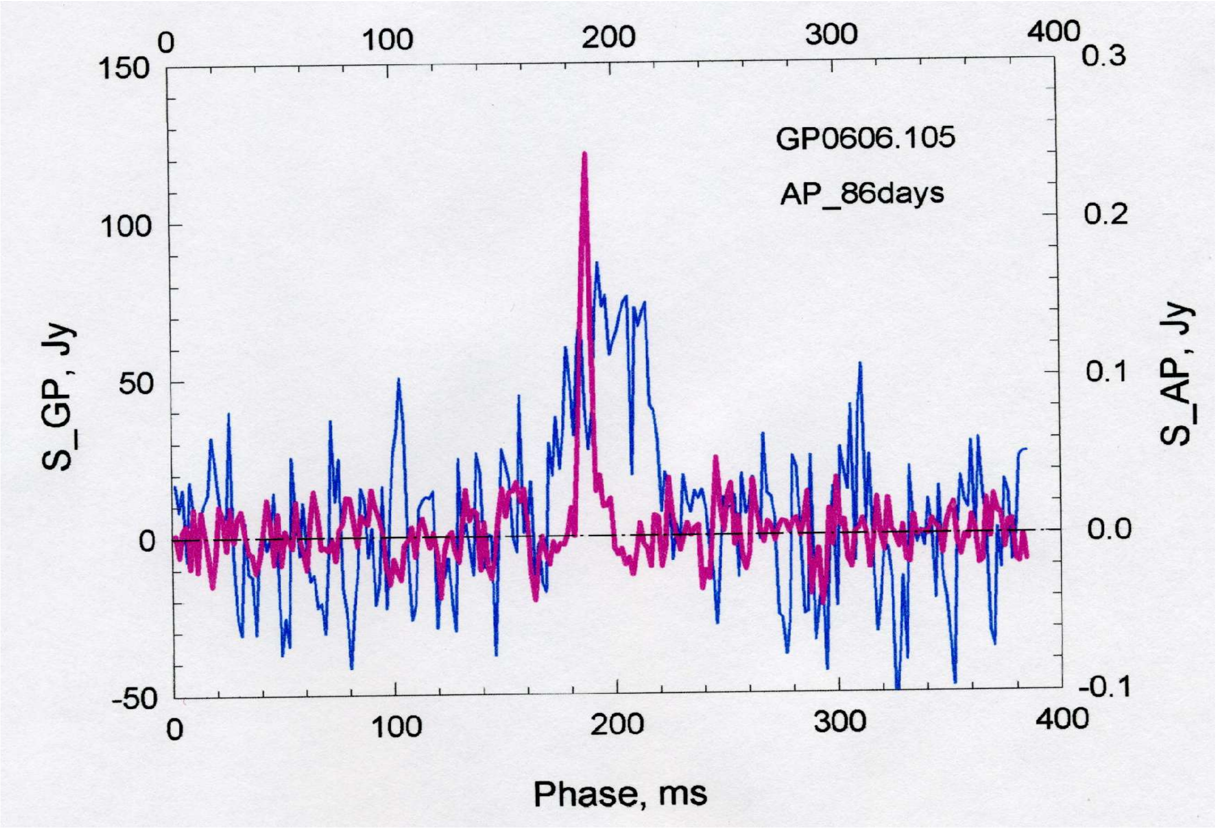
Kuzmin, Ersov, Losovsky have detected GPs in four pulsars
with an ordinary magnetic field at the light cylinder

PSR	B0031-07	B0656+14	B1112+50	J1752+2359
B_{LC}, G	7.0	770	4.2	71

These pulsars exhibit all characteristic features of the classical GPs

Giant pulse (red line) of the pulsar PSR B0656+14 with ordinary magnetic field at the light cylinder

S^{GP}=120 Jy



S^{AP}=0.18 Jy

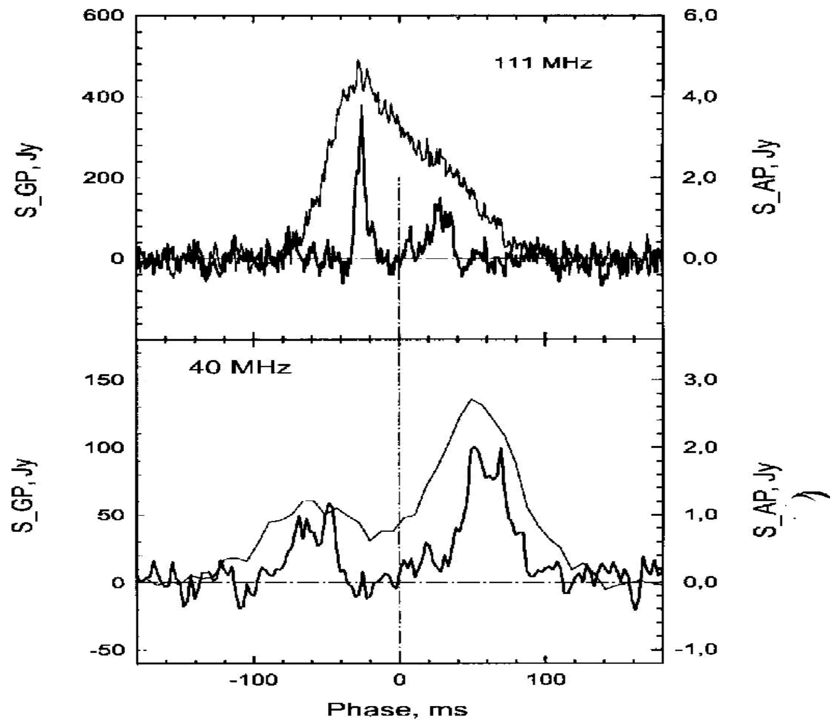
and the average pulse (sum of 44270 individual pulses) (blue line).

The observed peak flux density of GP exceeds the peak flux density of the average pulse by a factor of 630,

The energy excees of GP over the energy of AP by a factor of 120 is about the same as for GP of Crab pulsar and PSR B1937+21!

The plot of the average pulse is presented on a 500 times larger scale and flux densities of the observed GP and AP are shown separately on the left and right sides of the "y"-axis.

GPs of pulsar PSR B0031-07 are clustered in two different regions. This indicates that there are two emission regions of GPs. The separation of these regions at 40 MHz is larger than at 111 MHz. This is similar to the frequency dependence in the width of the AP, which is interpreted as a divergence of the magnetic field lines in the hollow cone model of pulsar radio emission. This suggests that the GPs from this pulsar originate in the same region as the AP, that is in a hollow cone over the polar cap instead in the light cylinder region.



(top) The double GP of pulsar PSR B0031-07(bold line) observed at 111 MHz together with the AP (thin line),

(bottom) The double GP (bold line), observed at 40 MHz together with the AP (thin line).

General properties of pulsar's giant pulses

PSR	P ms	lg B_{LC}, G	Freq, GHz	S^{GP}/S^{AP}	T_B, K	E^{GP}/E^{AP}	Reference
B0031-07	943	7	0.04	400	10^{28}	15	Kuzmin & Ershov 2004
J0218+43	2.3	3.2×10^5	0.61	-	-	51	Joshi et al 2004
B0531+21	33	9.8×10^5	2.23 5.5	5×10^5	10^{34} 10^{37}	80 -	Kostyuk et al 2003 Hankins et al 2003
B0540-69	50.5	3.5×10^6	1.38	5×10^3	-		Johnst & Romani 2003
B0656+14	385	770	0.11	600	10^{26}	110	Kuzmin & Ershov 2005
B1112+50	1656	4.2	0.11	80	-	10	Ershov & Kuzmin 2003
J1752+23	409	71	0.11	260	10^{28}	200	Ershov & Kuzmin 2006
B1821-24	3.0	7.2×10^5	1.51	-	-	81	Romani & Johnst 2001
J1823-30	5.4	2.5×10^5	6.85	-	-	64	Knight et al 2005
B1937+21	1.5	10×10^5	1.65	-	10^{39}	60	Soglasnovov et al 2004
B1957+20	1.6	3.8×10^5	0.61	-	-	129	Joshi et al 2004

Giant pulses are inherent for wide spectra of pulsar parameters: millisecond and long periodic ones, extremely high and ordinary magnetic field at the light cylinder. An energy excess of a GP burst over an energy of an average pulse is comparable one $E^{GP}/E^{AP} \approx 15$ -200.

Mechanisms of giant pulses radio emission

Giant pulses radio emission from the Crab pulsar results from the conversion of electrostatic turbulence in the pulsar magnetosphere by the mechanism of spatial collapse of nonlinear wave packets (Hankins T.H et al.,2003)

Giant pulses radio emission is generated in the electric discharge taking place due to the magnetic reconnection of field lines connecting the opposite magnetic poles (Istomin Ya.N., 2004)

Giant pulses are generated by means of coherent curvature radiation of charged relativistic solitons associated with sparking discharge of the inner gap potential drop above the polar cap (Gil, J & Melikadze G., 2004)

Giant pulses and their substucture can be explaining in the terms of induced Compton scattering of pulsar radiation off the particles of the plasma flow (Petrova S.A. 2004).

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