Amazing properties of giant pulses and the nature of pulsar's radio emission

Amazing properties of giant pulses…

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Amazing properties of giant pulses…

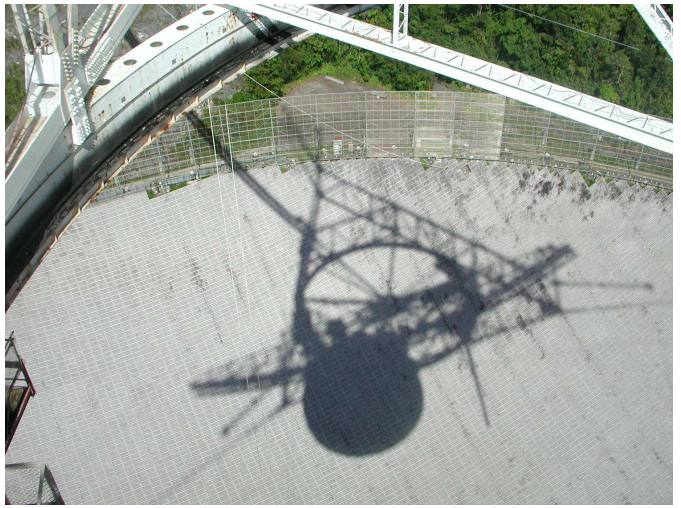
The telescopes:

2005 year:

TNA1500, 64-m dish, Kalyazin 0.6, 1.4, 1.6, 2.3 GHz, B=4—16 MHz
GBT, 100-m NRAO GB 2.2 GHz, B=64 MHz
305-m Arecibo, 3.2 GHz
ARO 40-m dish, Canada 2.2 GHz, B=16 Mhz

Kalyazin

Green Bank



Arecibo

Algonkin Park

Amazing properties of giant pulses…

The telescopes:

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TNA1500, 64-m dish, Kalyazin 0.6, 1.4, 1.6, 2.3 GHz, B=4—16 MHz
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Previous observations:

UTR2 (Ukraine), T-shape decametric array, 29 MHz, B=1.2 MHz
WSRT, 1.2 CHz, B=10 MHz
Northern Cross, Medicina, Italy, 409 MHz, B=2 MHz
64-m dish, Tidbinbilla, 1.6 GHz, B=32 MHz (2x16)
BSA, Pushchino, 111 MHz

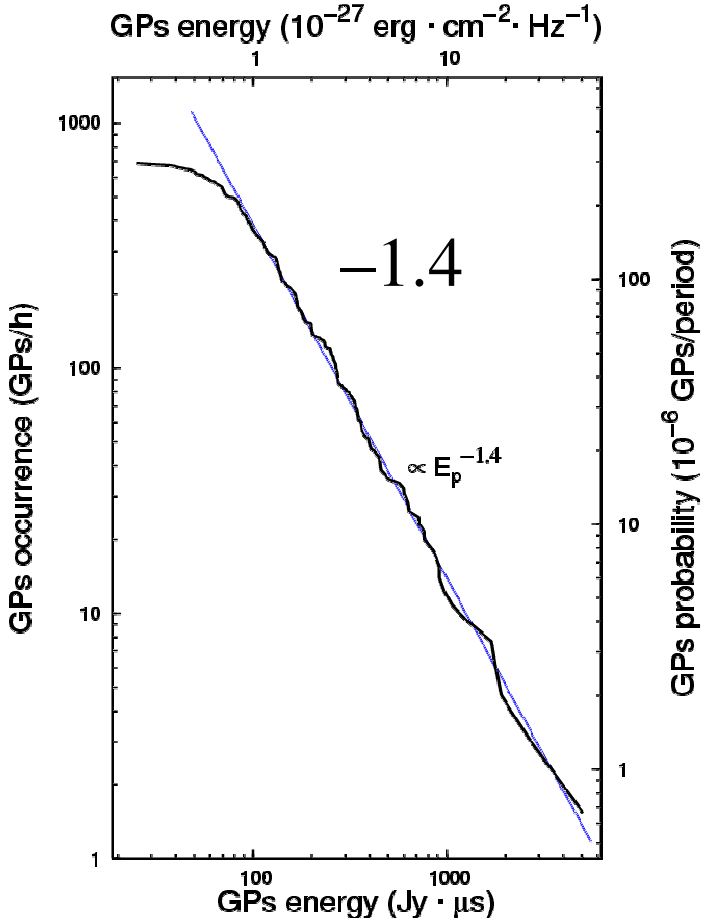
VLBI DAS S2, Mk5, K5, continuous record, coherent dedispersion

Amazing properties of giant pulses…:

"**Giant**"– what does it mean? **Most of giant pulses are not very giant. Height distribution of normal single pulses is close to lognormal (Ershov, 2006). Few pulsars emit, beside the normal, pulses of quite different type, which have power law height distribution. Waiting sufficiently long time, one can detect a very strong "giant" pulse, exceeding the average by 100, 1000, 1000???…, $10^?$ times.**

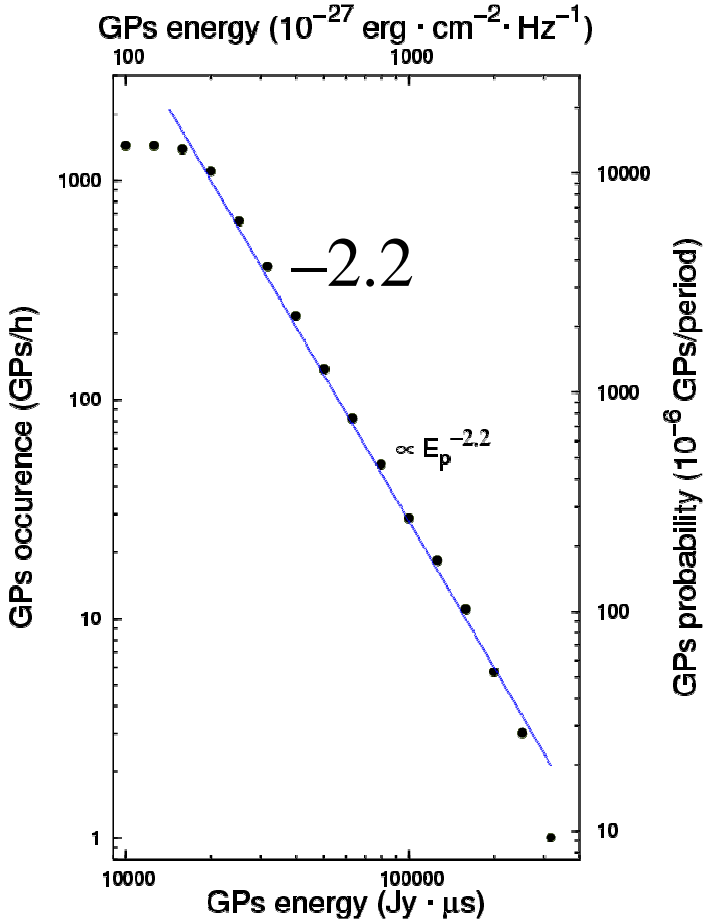
Cumulative distribution of giant pulse height

B1937+21



May 30, 1999, Tidbinbilla (Australia)
F = 1650 MHz, B = 2x16 MHz

Crab Pulsar



Kalyazin (Russia), Nov 24-26, 2003,
F = 594 MHz, B = 8 MHz

11 Pulsars with giant pulses

- **Crab Pulsar B0531+21** (Lundgren et al., 1995, ApJ, 453, 433)
- **B1937+21** (например, Soglasnov et al., 2004, ApJ, 616, 439)

- **B1821–24** (Romani & Johnston, 2001, ApJ, 557, L93)
- **B0540–69** **in LMC** (Johnston & Romani, 2003, ApJ, 590, L95)
- **B1957+20** **binary** (Joshi et al., 2003, IAU Symp. 218, p. 319)
- **J0218+4232** **binary** (Joshi et al., 2003, IAU Symp. 218, p. 319)
- **J1823–3021A** (Knight et al., 2005, ApJ, 625, 951)
- **B1112+50** (Ershov & Kuzmin, 2003, Astron. Lett., 29, 91)
- **B0031–07** (Kuzmin et al., 2004, Astron. Lett., 30, 247)
- **J1752+2359** (Ershov & Kuzmin, 2005, A&A, 443, 593)
- **B0656+14** (Ershov & Kuzmin, 2006, submitted)

Properties of giant pulses

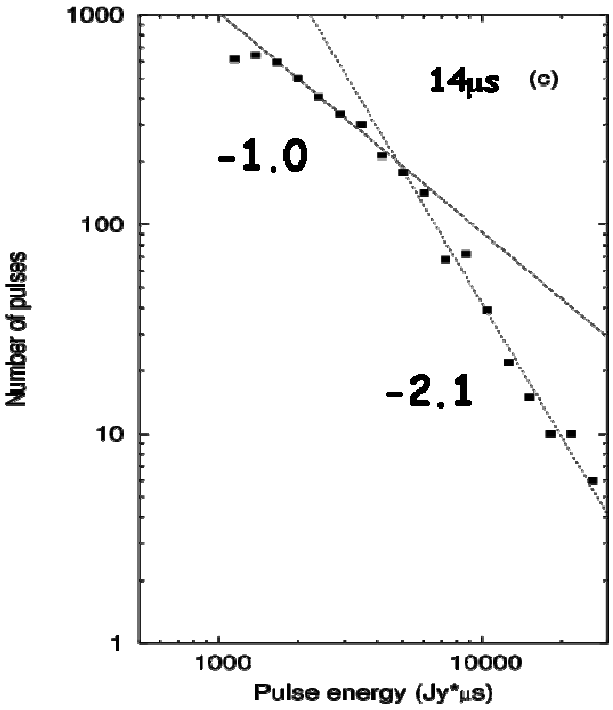
1.Intensity

How *weak* giant pulse may be?

How *strong* giant pulse may be?

How weak giant pulse may be?

Power law distribution can not be continued up to zero intensities. There are observational indications on the existence of low intensity cutoff, direct for the Crab pulsar (*Popov and Stappers, 2006*) and indirect but definite for the millisecond pulsar 1937+21 (*Soglasnov et al., 2004*).



Power index break and cutoff at low intensities of cumulative energy distribution of giant pulses of the Crab pulsar.
Nov 2003, WSRT, f=1200MHz

Q: **How weak giant pulse may be?**

A: Crab: Smin=100 Jy (main pulse)
Smin=25 Jy (interpulse)

MSP: Smin=16 Jy (main pulse)
Smin= 5 Jy (interpulse)

:

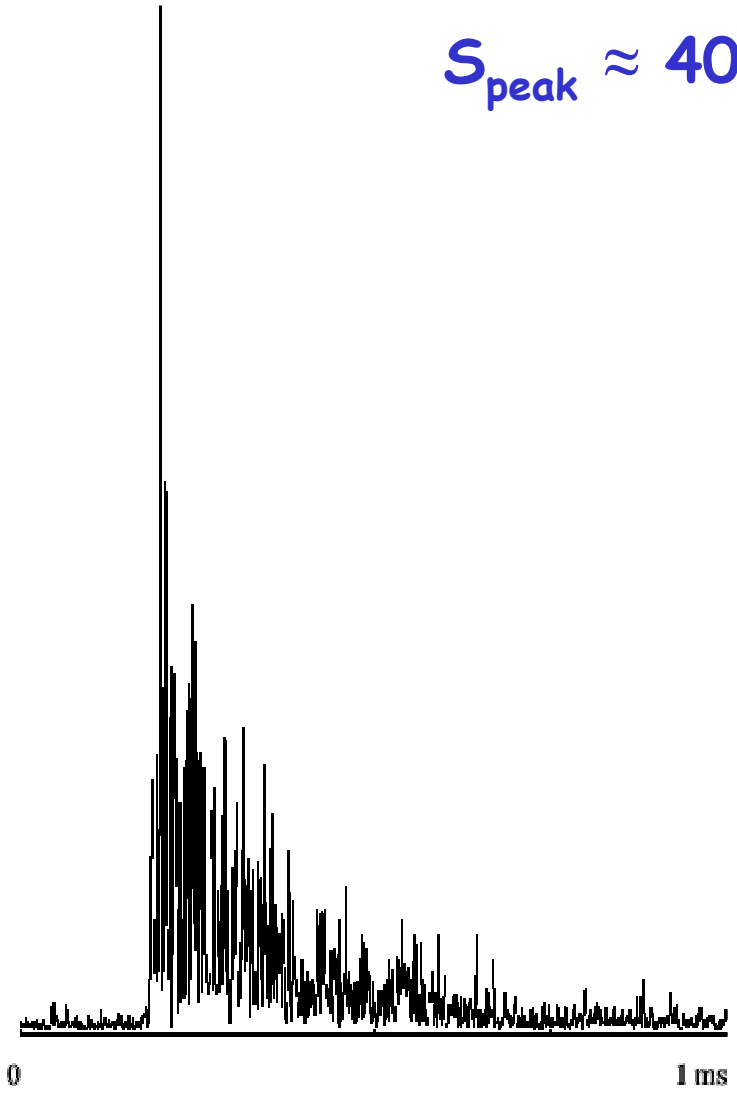
How strong giant pulses may be?

Nobody knows.

Obviously, peak flux density of giant pulses must have some upper limit. However, at present time there are no indications on the cutoff or steepness of distribution at high intensities. ***Wait longer – detect the pulse stronger*** – up to kJy, MJy, *etc*.

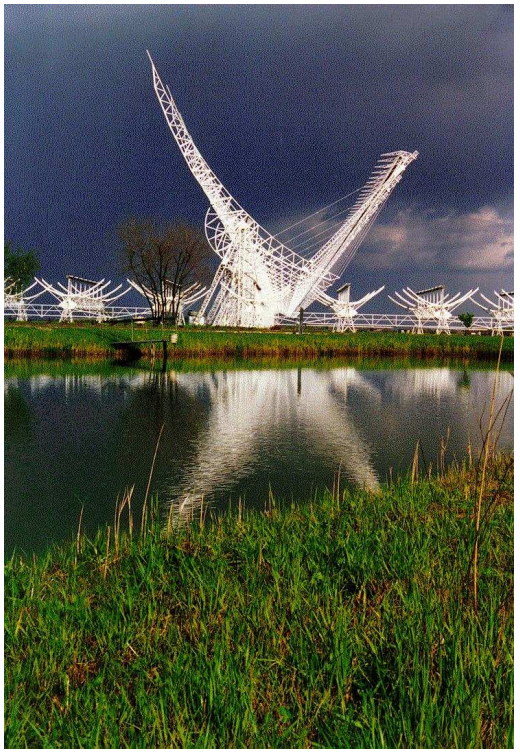
The strongest giant we detect at the moment have peak flux density 60 kJy (MSP) and 7 MJy (Crab).

The first really strong giant (Crab)

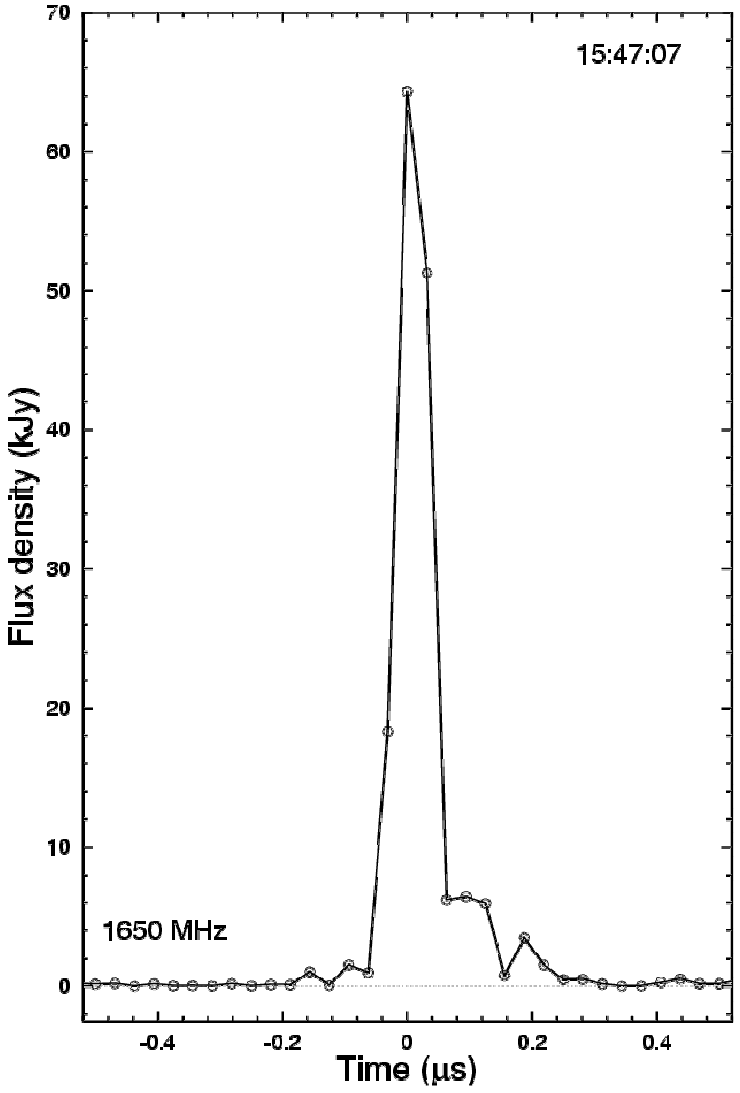


$S_{peak} \approx 400000$ Jy

9 May 2000
N-Cross, Medicina (Itay)
F = 408 MHz
B = 2 MHz



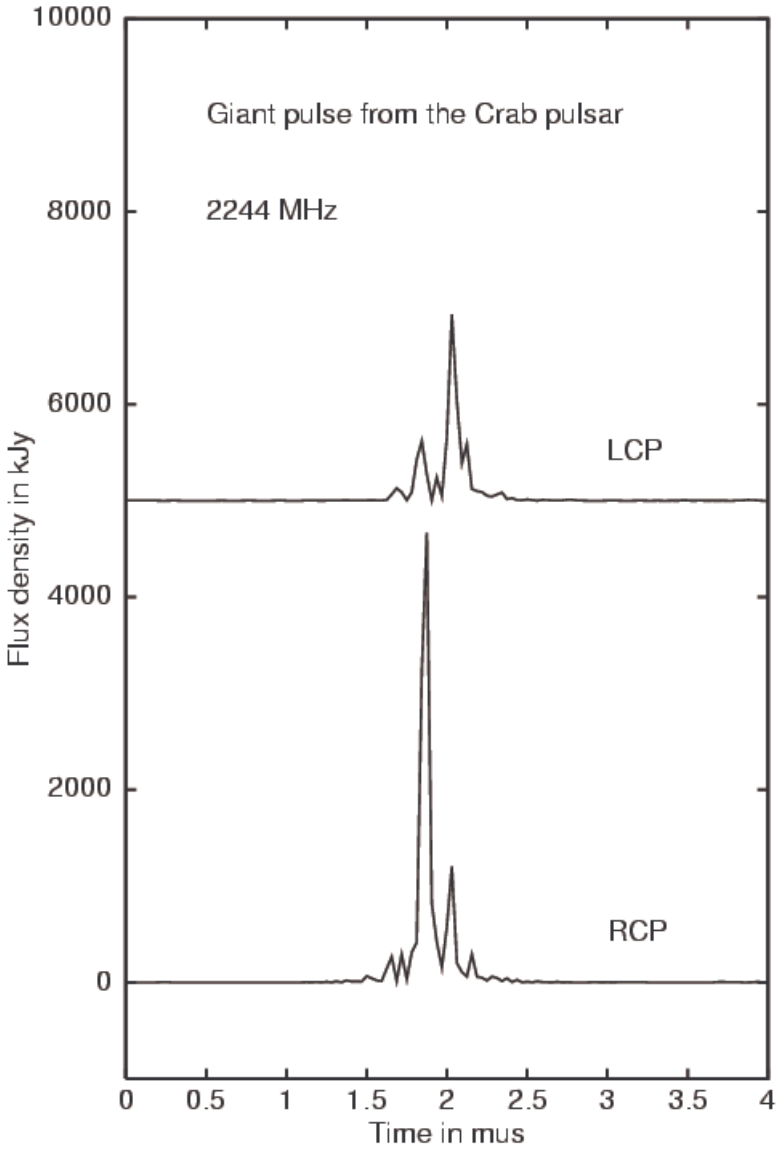
The strongest from MSP



$S_{peak} \approx 65\ 000$ Jy

30 May 1999
Tidbinbilla (Australia)
F = 1650 MHz
B = 2x16 MHz

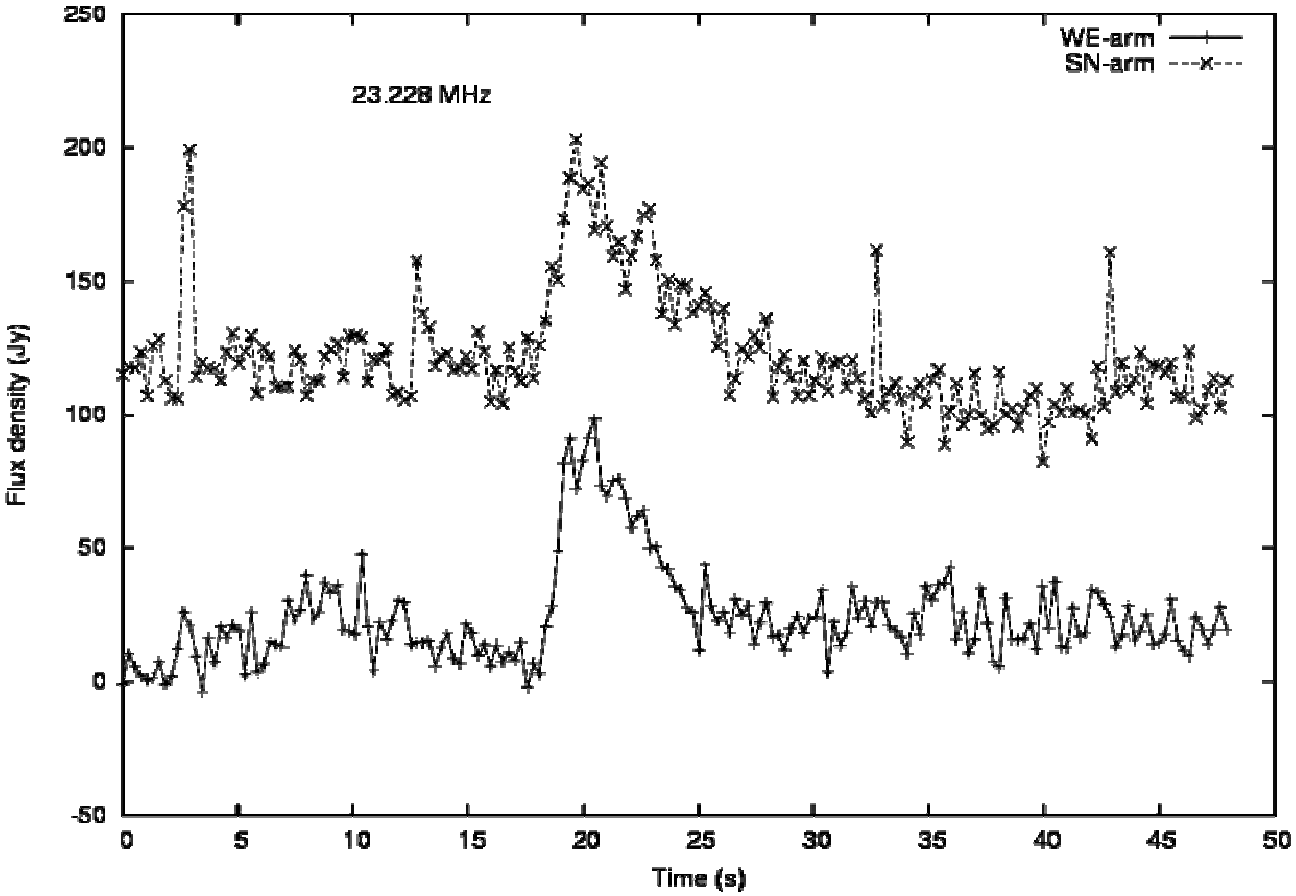
Crab: the first millionaire



$S_{peak} \approx 5$ MJy

March 2005
Kayazin
F = 2244 MHz
B = 16 МГц

Crab: the strongest at the lowest frequency



$S_{peak} \approx 100$ Jy

March 2005
Kharkov
F = 23.2 MHz
B = 1.6 МГц

Scattering time = **4s (!)**

Properties of giant pulses

2. Duration & waveform
MSP

Giant pulses are very short events. In the millisecond pulsar B1937+21 they are unresolved in all our observations, their time duration is less than 16 ns. Only few from thousands have some inner structure different than scattering waveform.

Properties of giant pulses

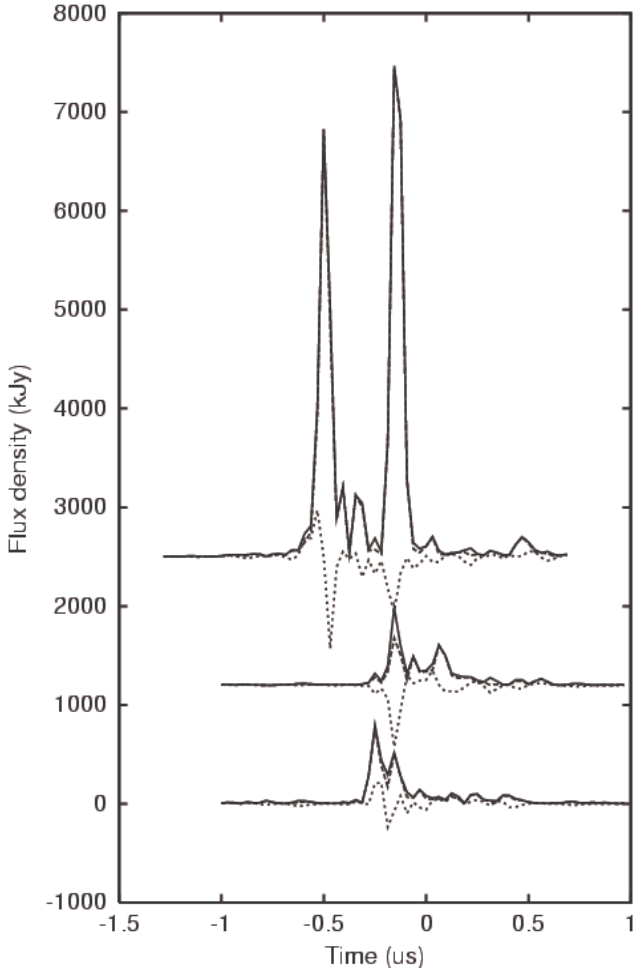
2. Duration & waveform
Crab

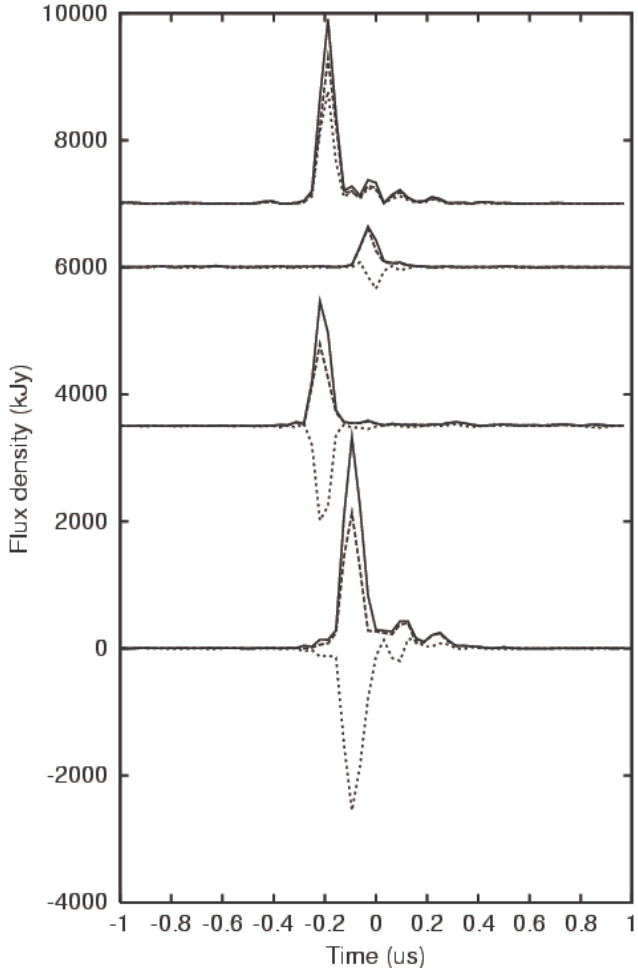
Giant pulses from the Crab pulsar also may be very short, but most of them have more complex structure.

Properties of giant pulses

2. Duration & waveform

Crab pulsar: short giant pulses

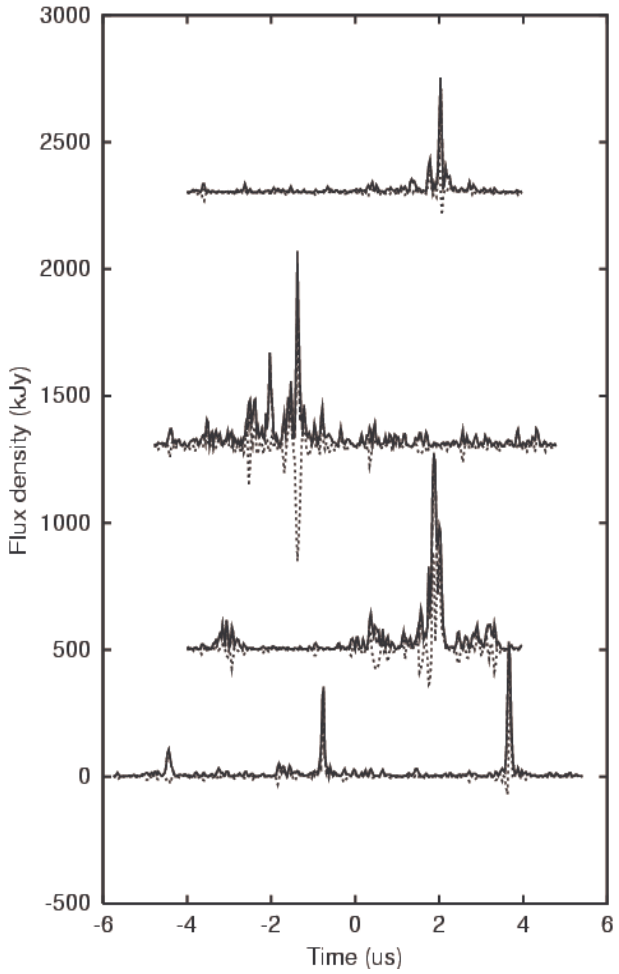


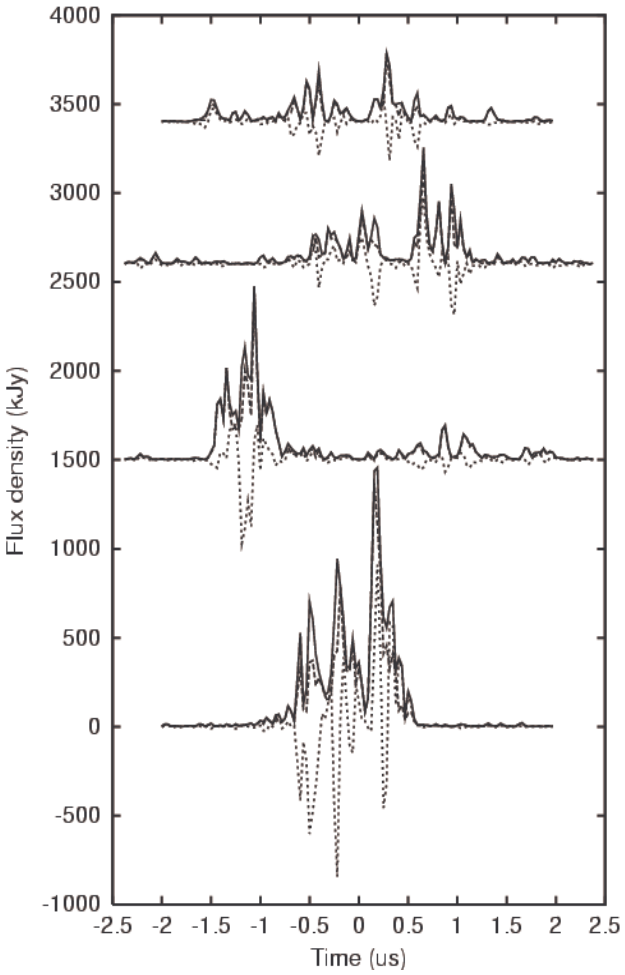


Properties of giant pulses

2. Duration & waveform

Crab pulsar: wide giant pulses

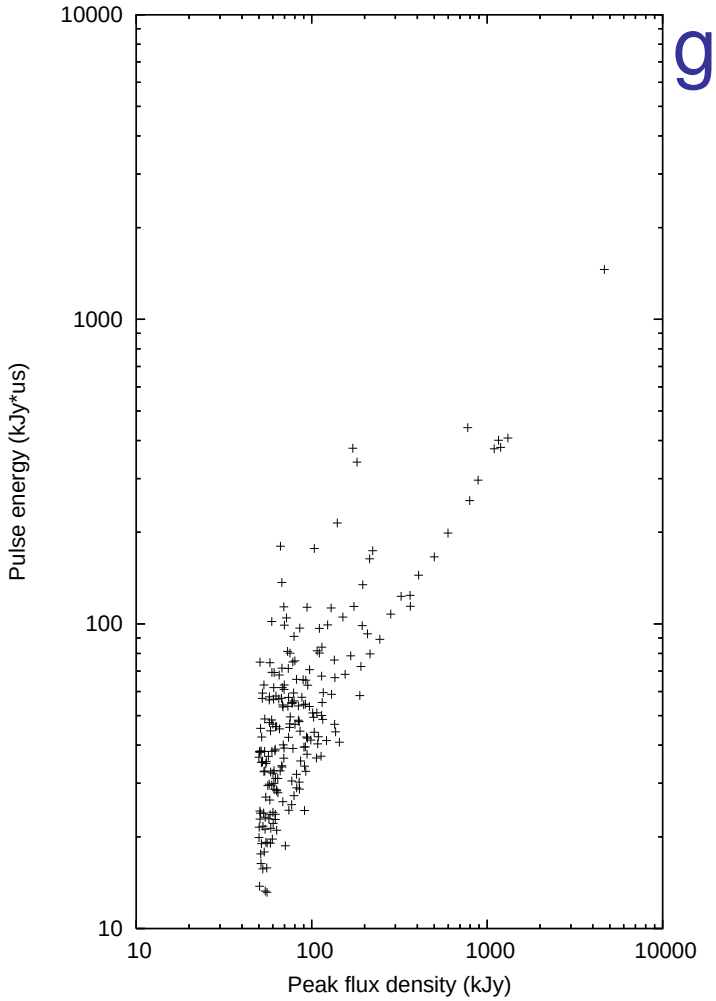




Properties of giant pulses

2. Duration & waveform

Giant pulses with peak flux density greater than 30 kJy are the shortest



Crab f=1.4 GHz, Kalyazin

Dependence between peak flux density and flux density integrated over the whole pulse duration (“energy”)

Properties of giant pulses

3. Polarization

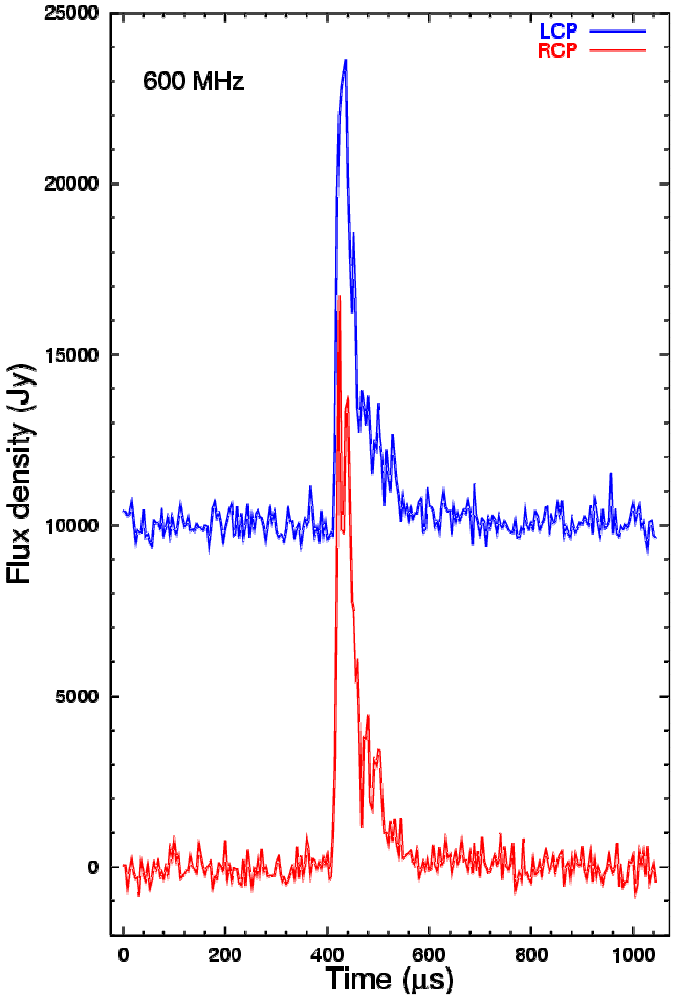
Giant pulses, both In the Crab pulsar and in B1937+21, are highly polarized. The polarization may be:

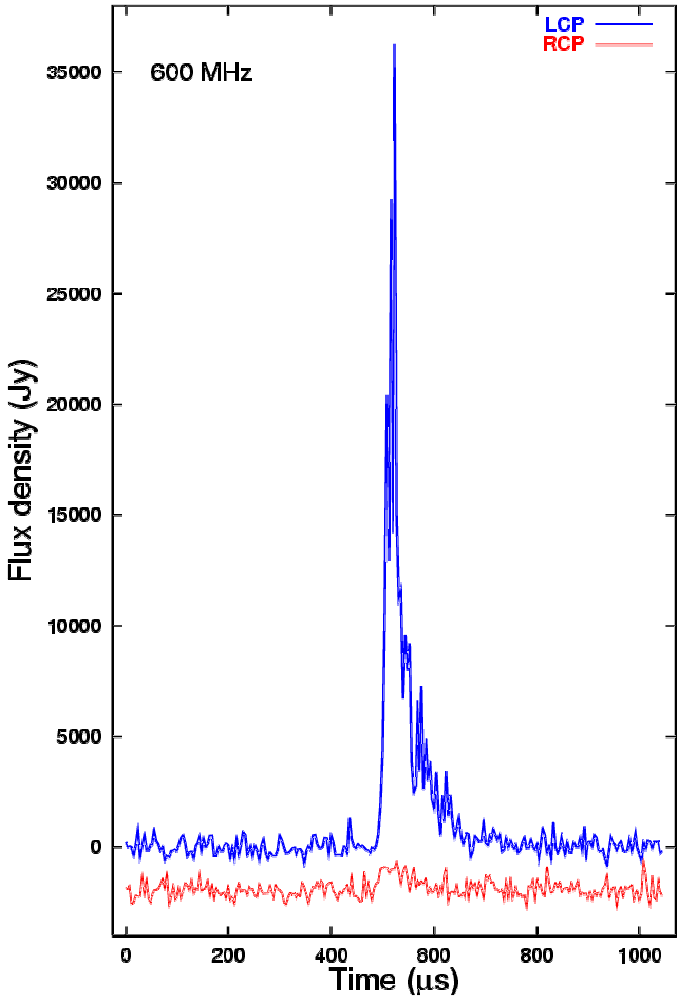
-- pure circular RCP
-- pure circular LCP
-- pure linear
-- elliptical
-- rapidly changing

MSP: 60% of peaks are 100% circularly polarized!

Properties of giant pulses

3. Polarization

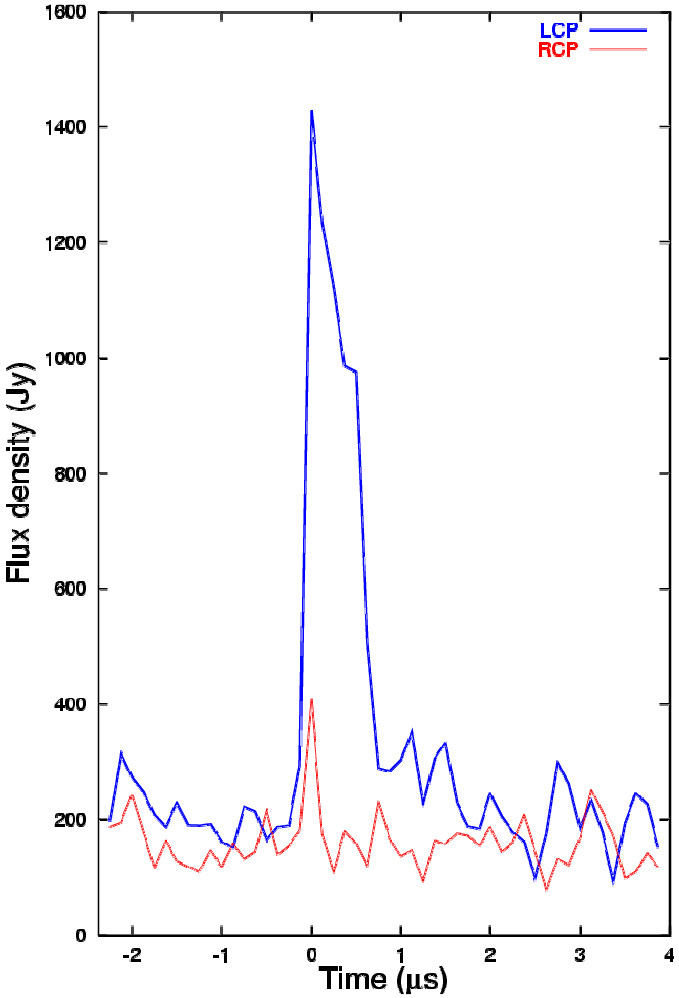


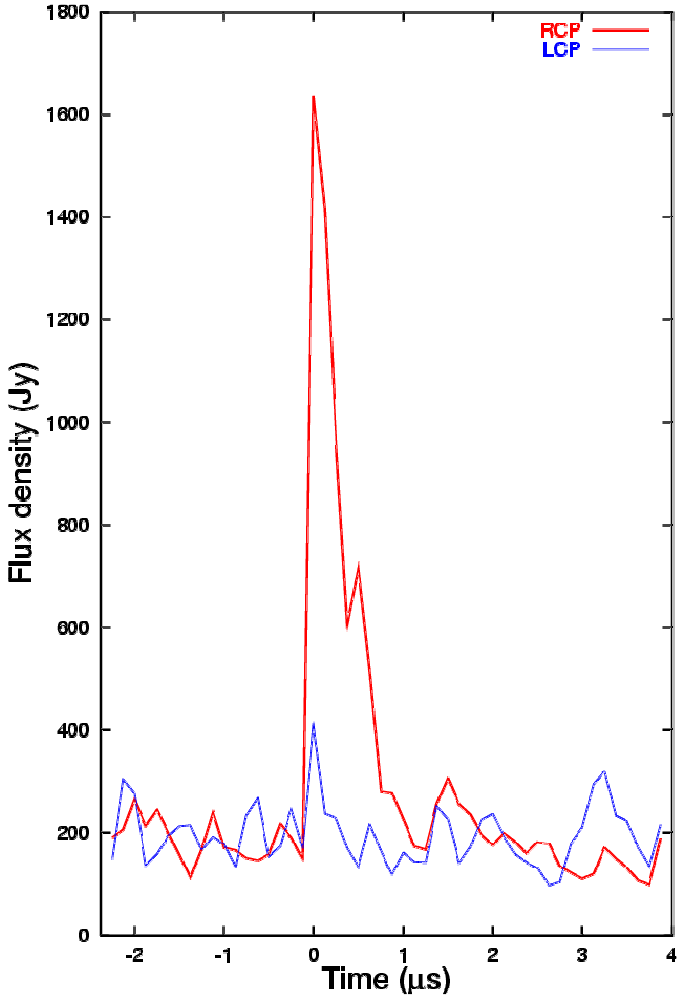


Crab, Kalyazin, Nov 24-26, 2003, F = 594 MHz, B = 8 MHz

Properties of giant pulses

3. Polarization





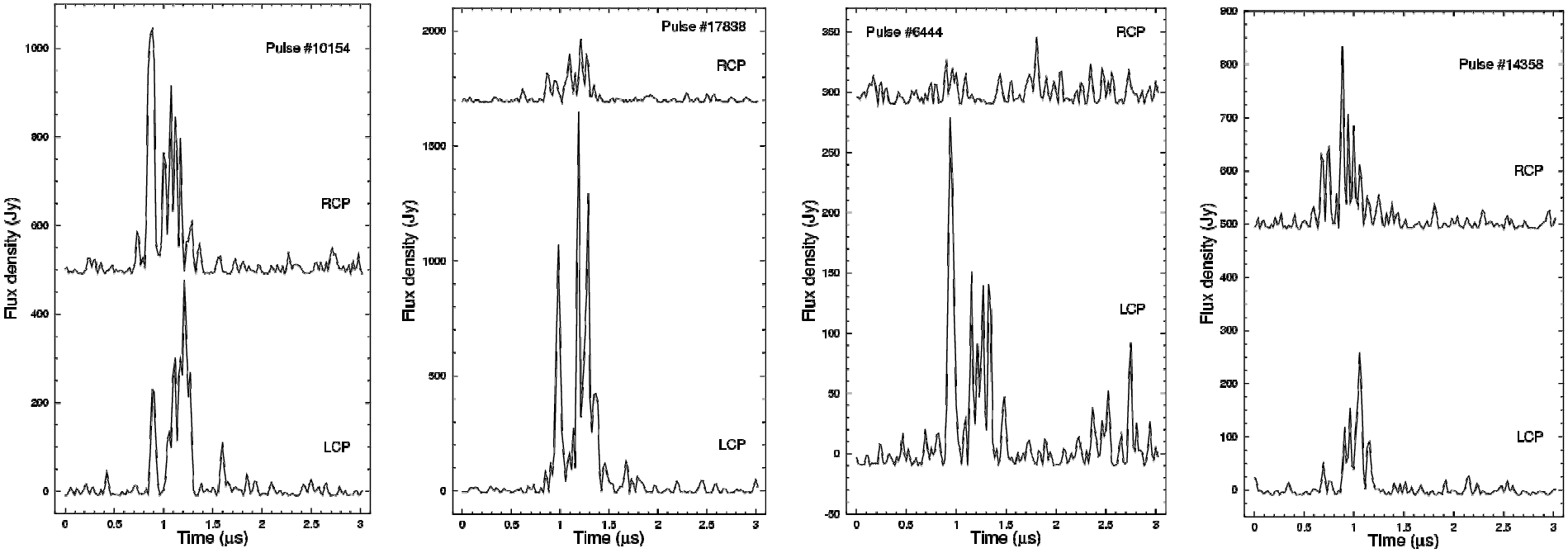
MSP, Kalyazin, July 24, 2002, F = 594 MHz, B = 8 MHz

Properties of giant pulses

3. Polarization

B1937+21

26 March 2004, 100-m GBT
f=1400 MHz B = 26 MHz



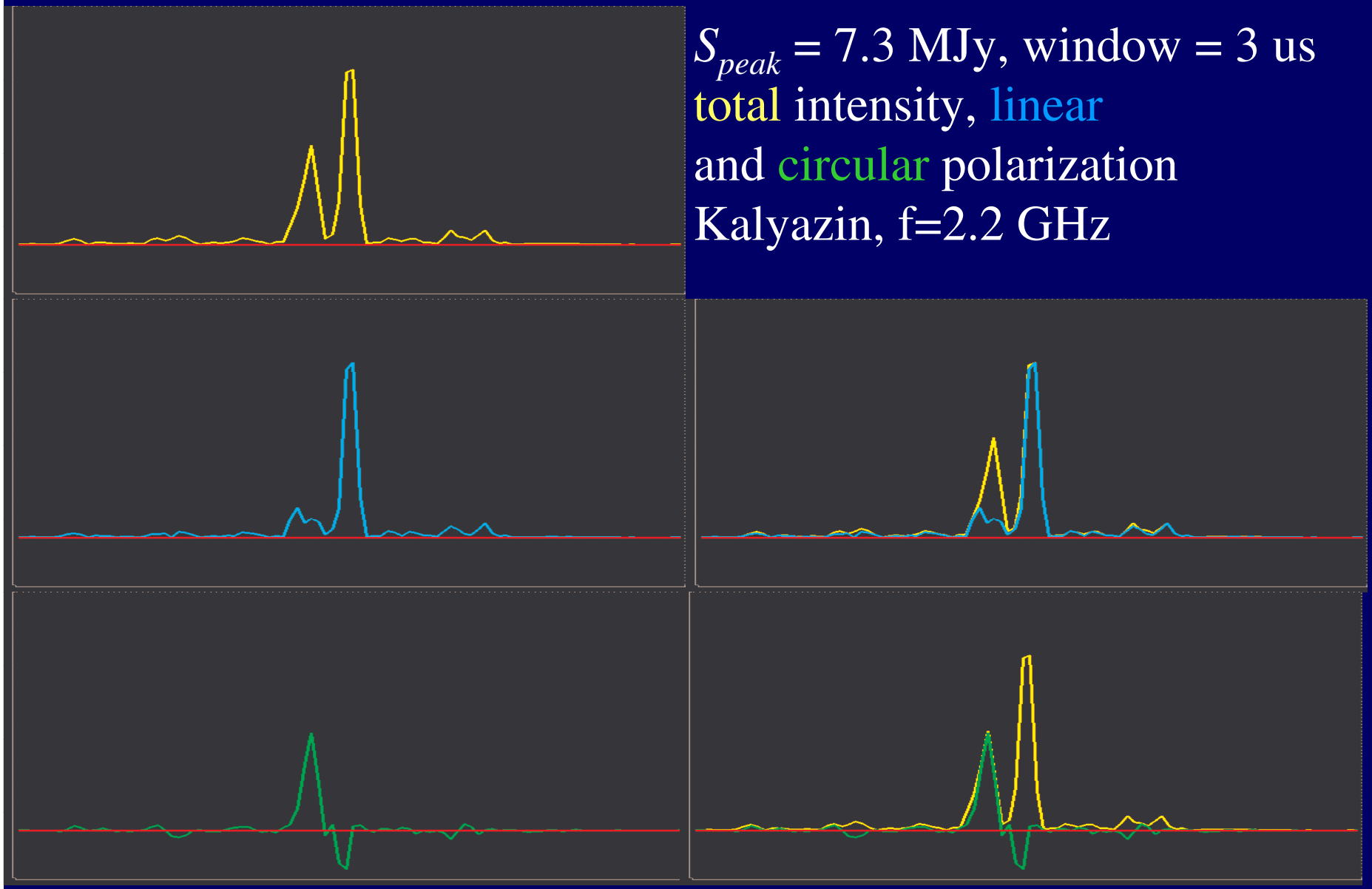
Polarization of giant pulses

High polarization degree of GPs and their coponents

Linear, circular (both signs) – up to 100%, elliptical, either pure or variously mixed

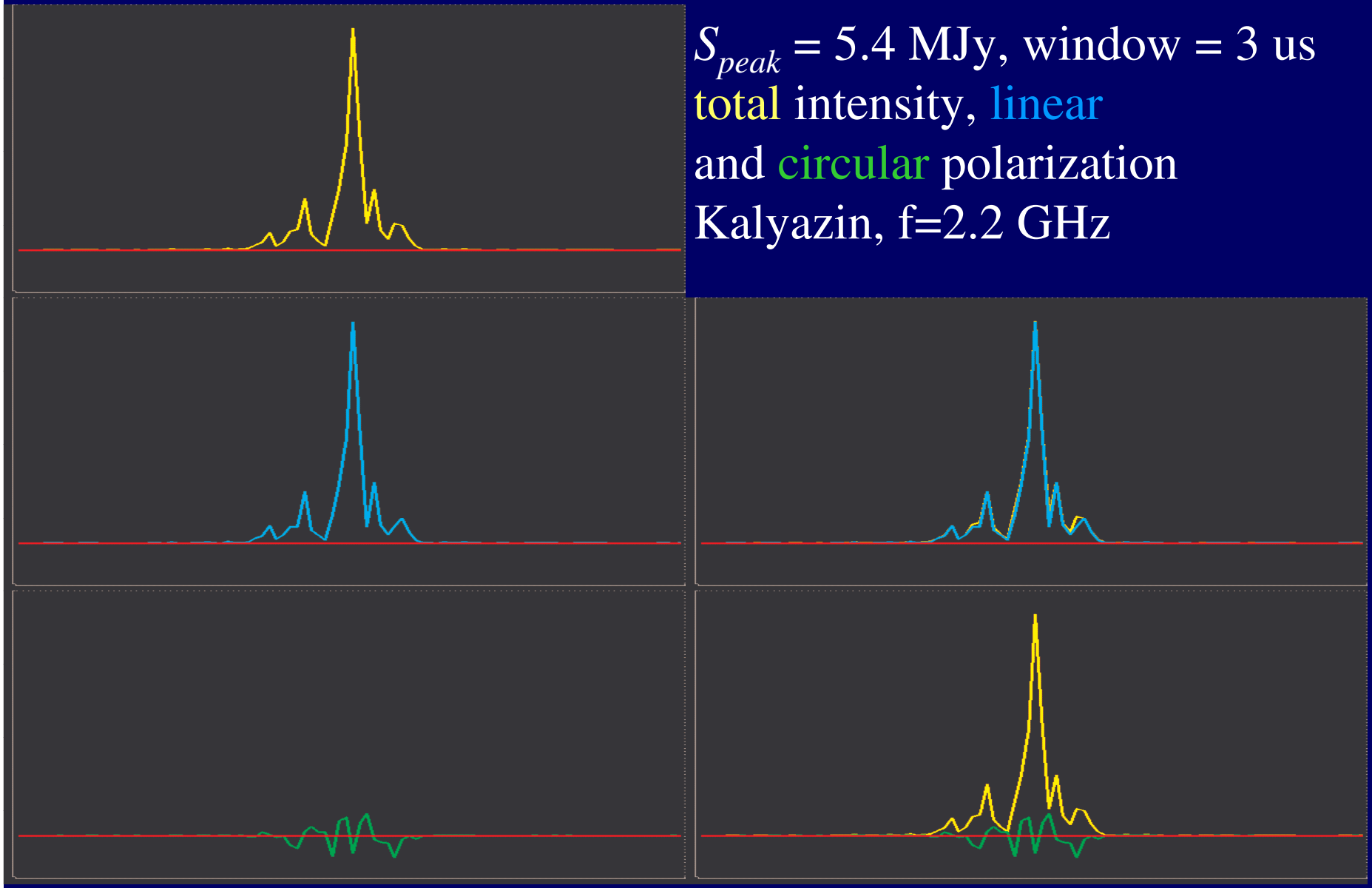
Rapid jumps from circular to linear and opposite
Rapid jumps of circular polarization sign

Zoo GP: polarization (Crab)



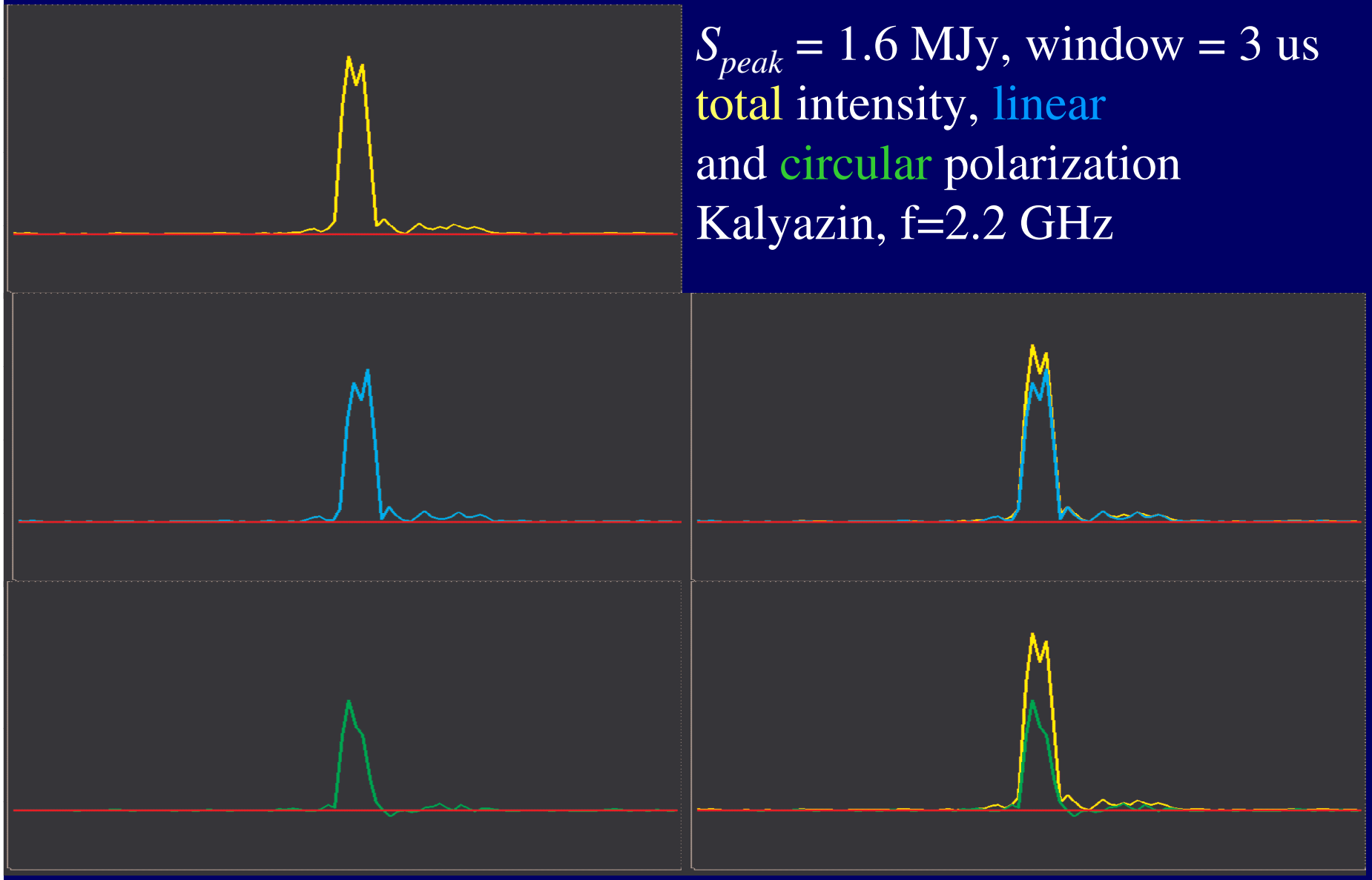
S_{peak} = 7.3 MJy, window = 3 us
total intensity, linear
and circular polarization
Kalyazin, f=2.2 GHz

Zoo GP: polarization (Crab)



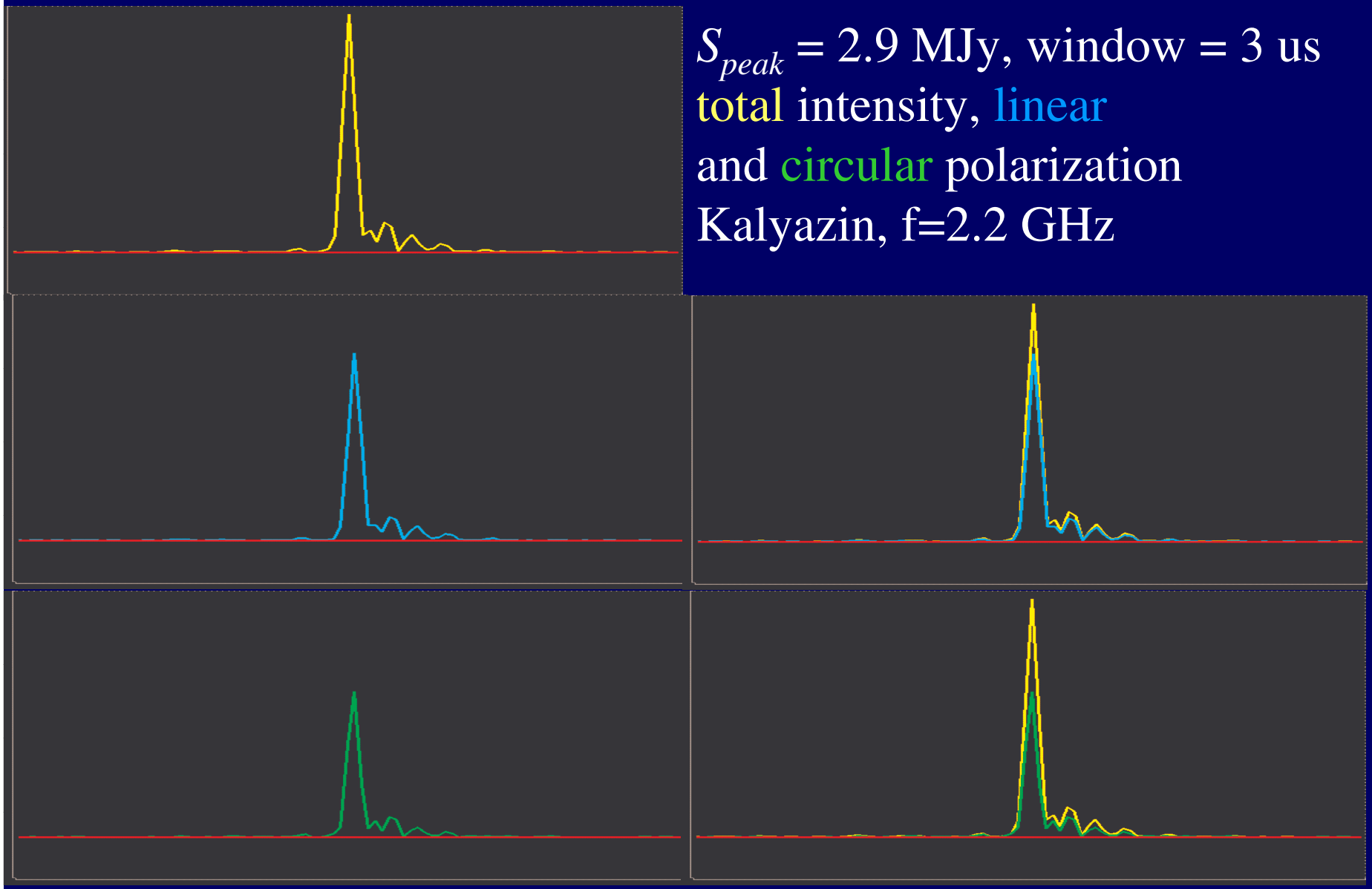
S_{peak} = 5.4 MJy, window = 3 us
total intensity, linear
and circular polarization
Kalyazin, f=2.2 GHz

Zoo GP: polarization (Crab)



S_{peak} = 1.6 MJy, window = 3 us
total intensity, linear
and circular polarization
Kalyazin, f=2.2 GHz

Zoo GP: polarization (Crab)

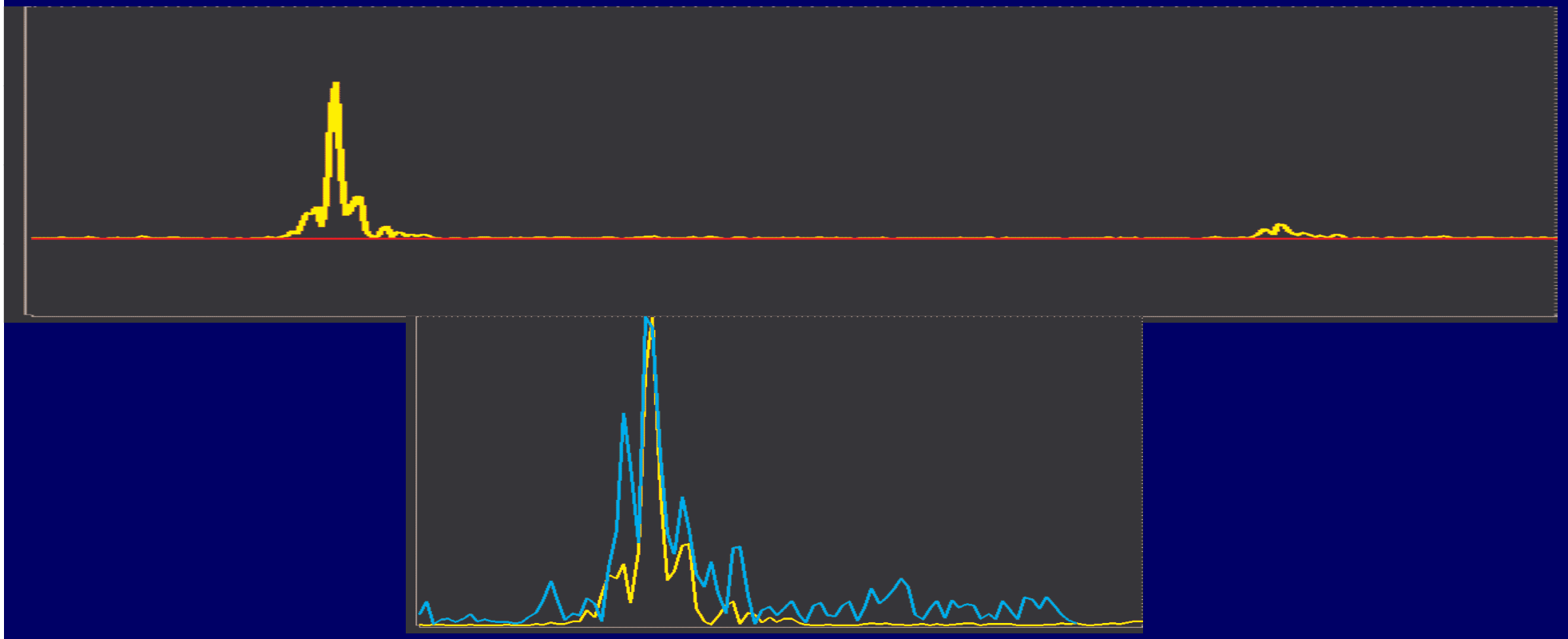


S_{peak} = 2.9 MJy, window = 3 us
total intensity, linear
and circular polarization
Kalyazin, f=2.2 GHz

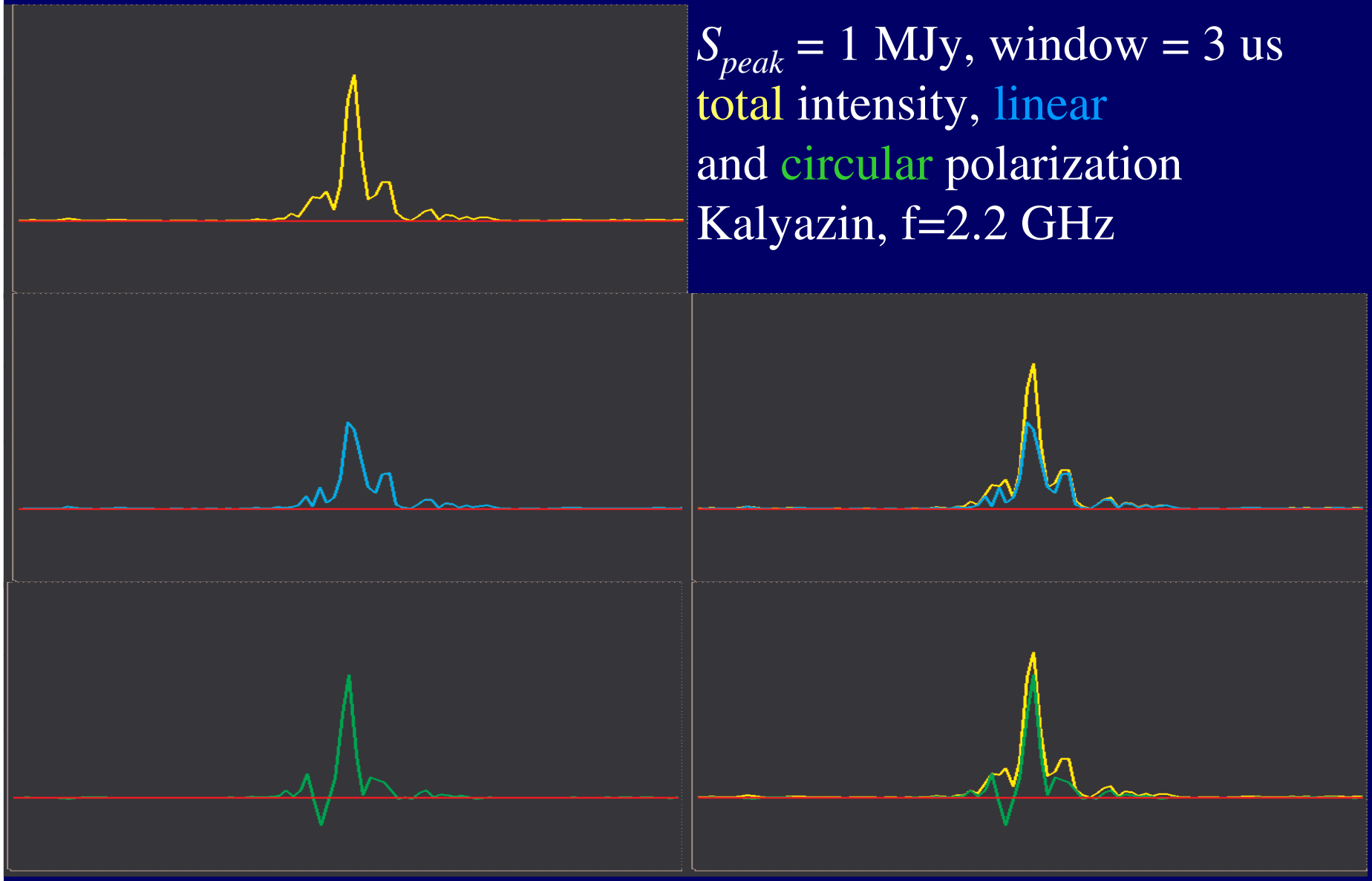
Zoo GP: polarization (Crab)

S_{peak} = 1 MJy, window = 10 мкс, total intensity

«Echo» GP? Scattering?

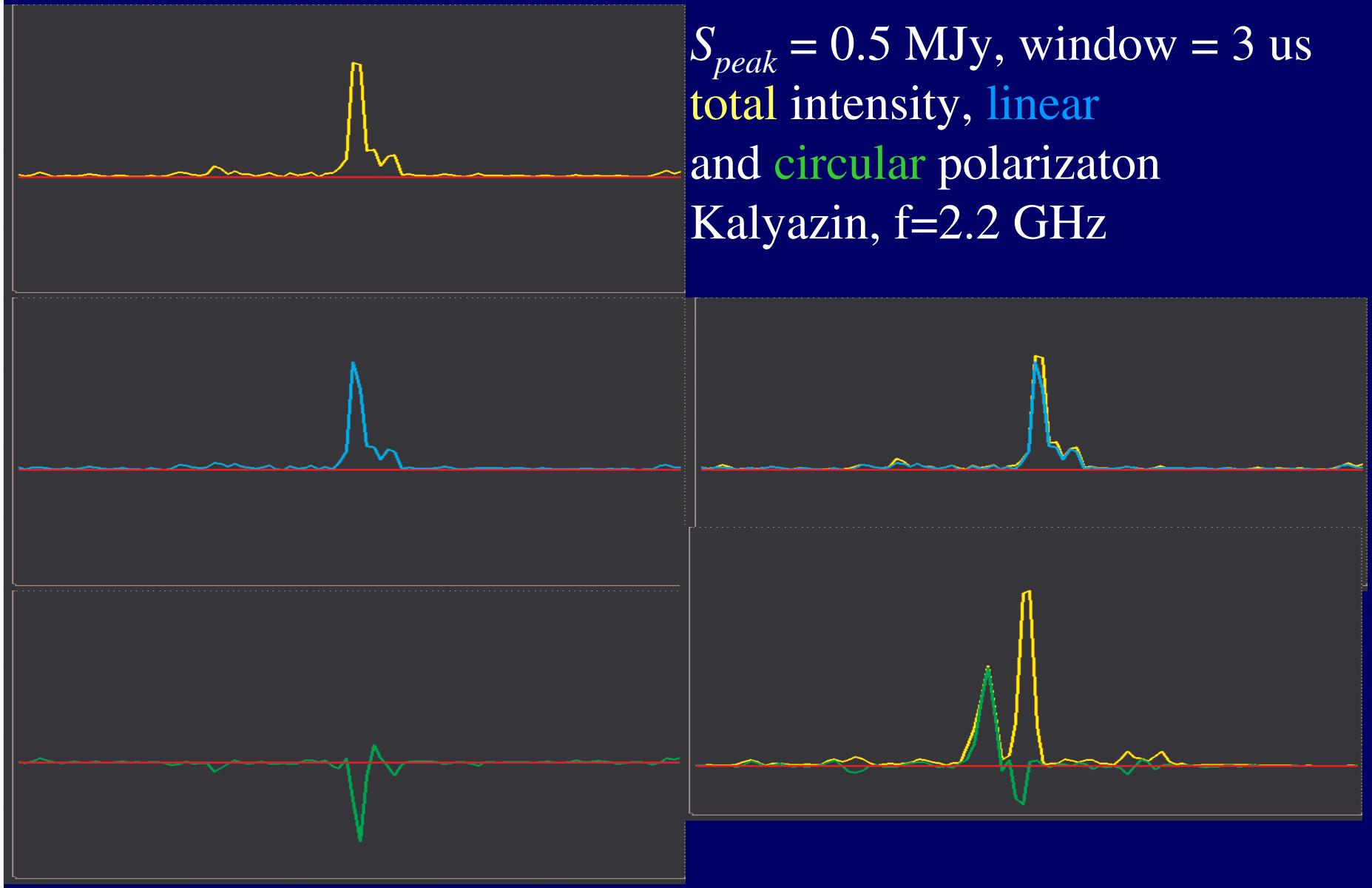


Zoo GP: polarization (Crab)



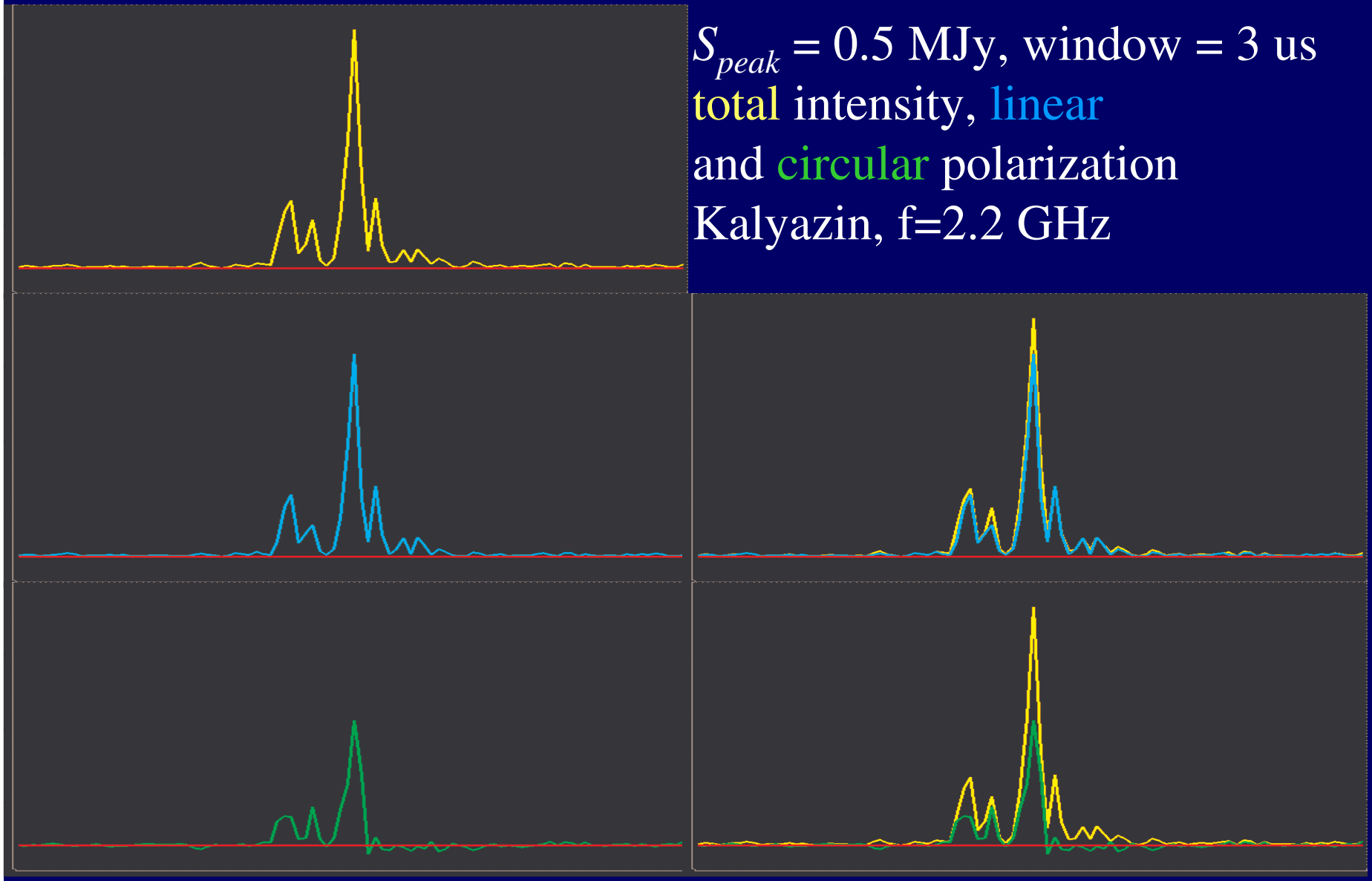
S_{peak} = 1 MJy, window = 3 us
total intensity, linear
and circular polarization
Kalyazin, f=2.2 GHz

Zoo GP: polarization (Crab)



S_{peak} = 0.5 MJy, window = 3 us
total intensity, linear
and circular polarizaton
Kalyazin, f=2.2 GHz

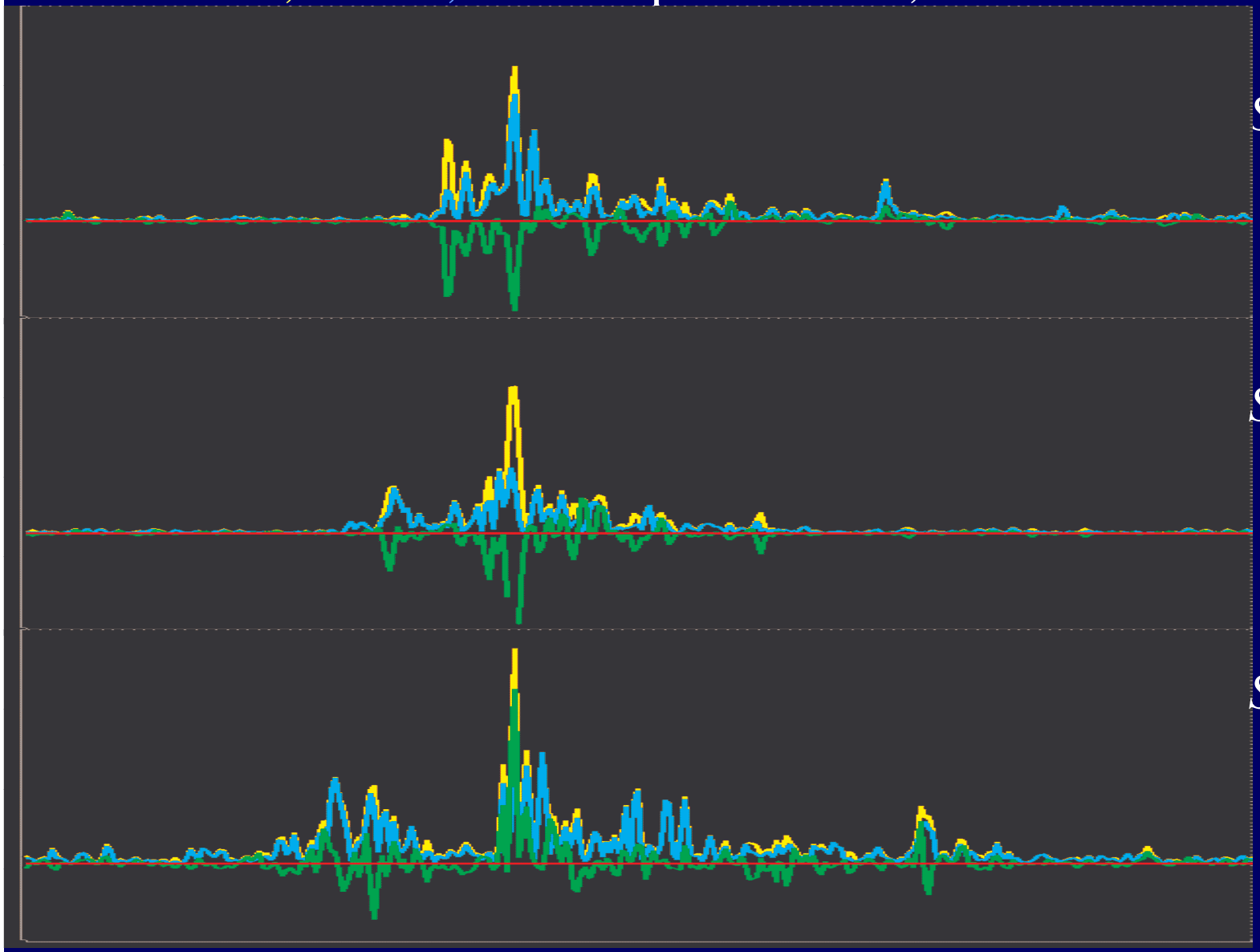
Zoo GP: polarization (Crab)



S_{peak} = 0.5 MJy, window = 3 us
total intensity, linear
and circular polarization
Kalyazin, f=2.2 GHz

Zoo GP: polarization (Crab)

Total, linear, circular polarization, wide GPs



S_{peak} = 0.3 MJy
window = 10 us

S_{peak} = 0.3 MJy
window = 10 us

S_{peak} = 0.1 MJy
window = 10 us

Zoo GP: polarization (Crab)

Total, linear, circular polarization, wide GPs

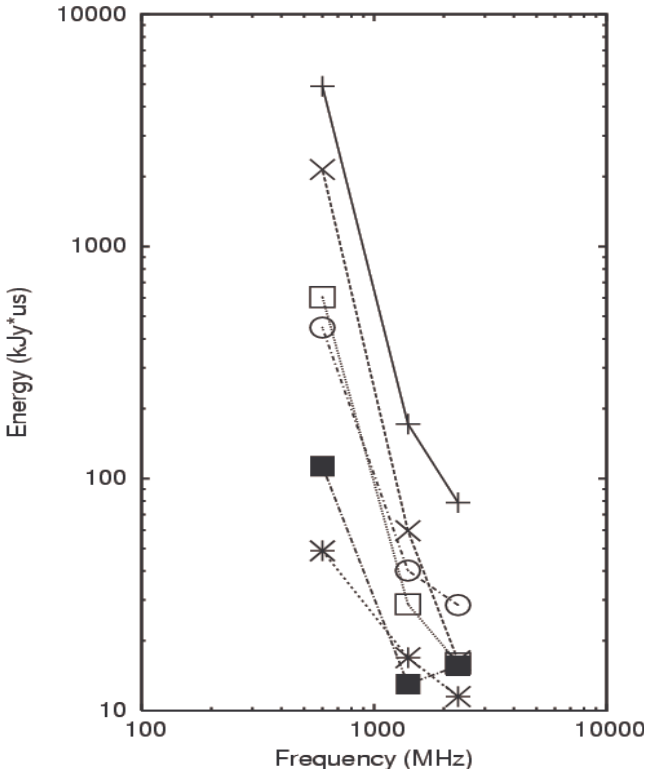
S_{peak} = 0.14 MJy
window = 10 us

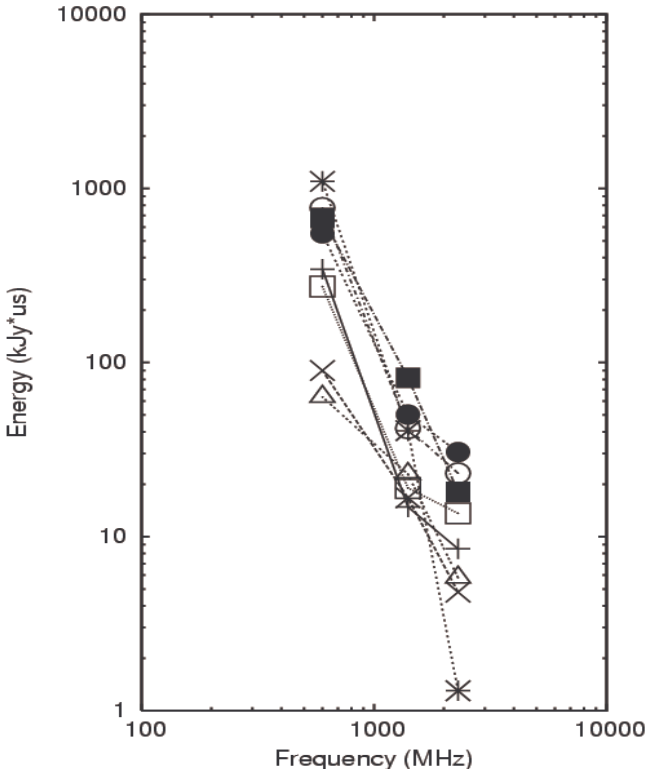
S_{peak} = 0.14 MJy
window = 15 us

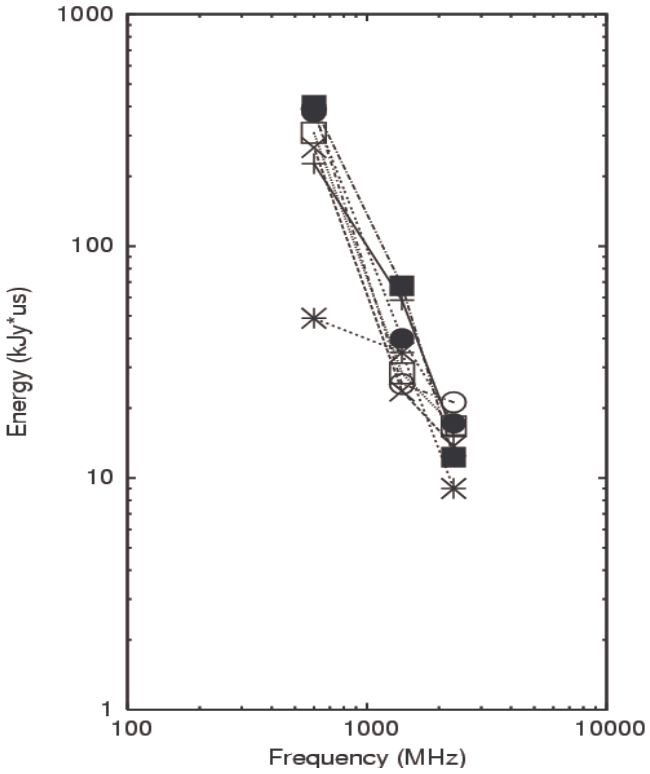
S_{peak} = 0.1 Mjy
window = 10 us

Properties of giant pulses

4. Spectra







f (МГц)	23	111	600	1400	2200
23			-2.7		
111			-2.7		
600				-2.6	-2.3
1400					-1.8
2200					

Crab pulsar

Spectral indices:

+0.4 ÷ -4.0