Detailed study of giant pulses from the millisecond pulsar B1937+21

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Outline

- Background
- Observations
- GPs summary, width and energy distributions
- Polarization properties of GPs
- Estimations of T_b and u_{GP}
- Conclusions

Background

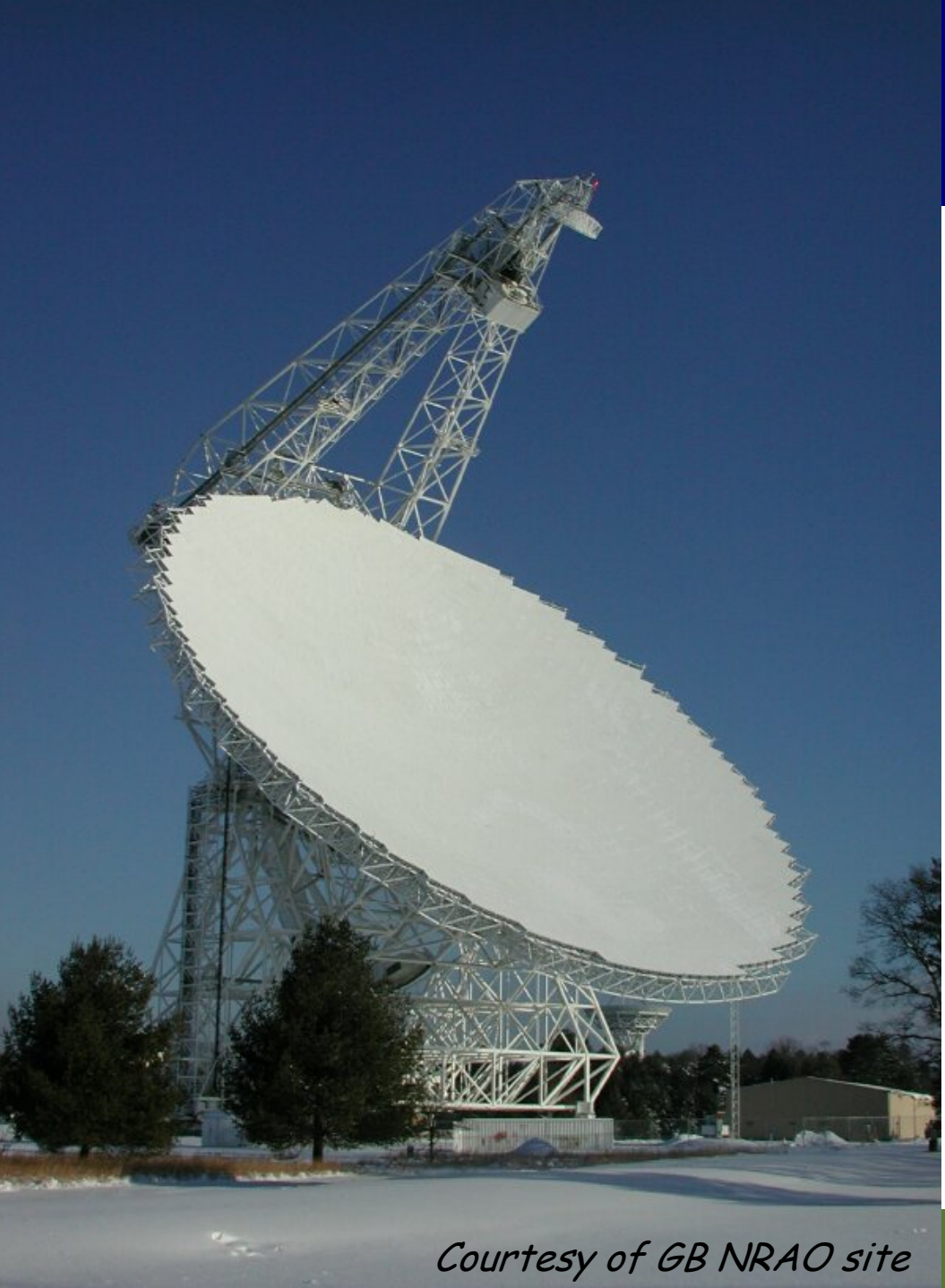
1. Wolszczan et al. 1984, in Milliseconds Pulsars (Green Bank: NRAO), 63
   Sallmen & Backer, 1995, ASP Conf. Ser. 72, p. 340
   first reports about small number of strong pulses which are reminiscent of GPs from the Crab

2. Cognard et al., 1996, ApJ, 457, L81
   Arecibo @ 430 MHz, 44min
   phases of occurrence (delayed by 40-50 μs), 100% circular polarization,
   power-law energy distribution with α = -1.8

3. Kinkhabwala & Thorsett, 2000, ApJ, 535, 365
   Arecibo @ 430, 1420, 2380 MHz (30min, 4h, 26min)
   spectrum of GPs: ~ -3.1, GPs window ~ 10 μs

4. Soglasnov et al., 2004, ApJ, 616, 439
   70-m Tid @ 1650 MHz, B=32 MHz, 39min
   309 GPs, true widths < 15ns, $T_b > 5 \cdot 10^{39}$K for the strongest GP with S_{peak} = 65 kJy
   GPs don't affect the regular MP or IP
   energy distribution is power-law with index of -1.4

100-m GBT



Courtesy of GB NRAO site

Mark5A recording system was used in single dish mode

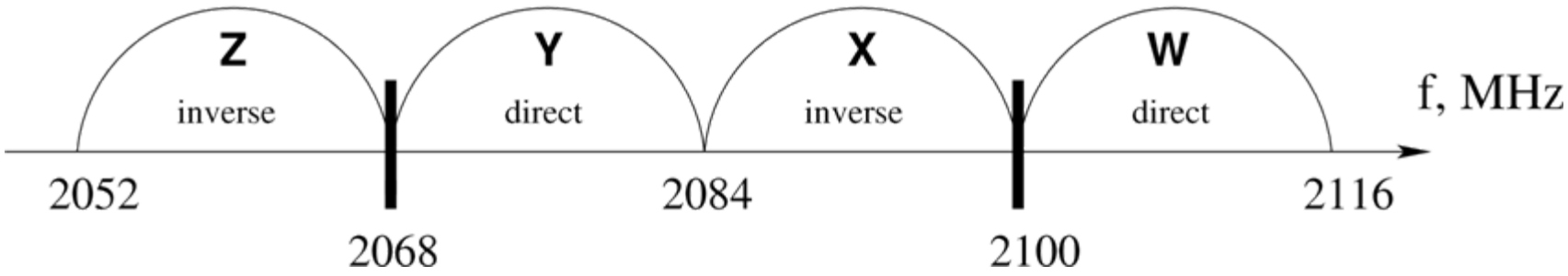
For the first time

Observational configuration

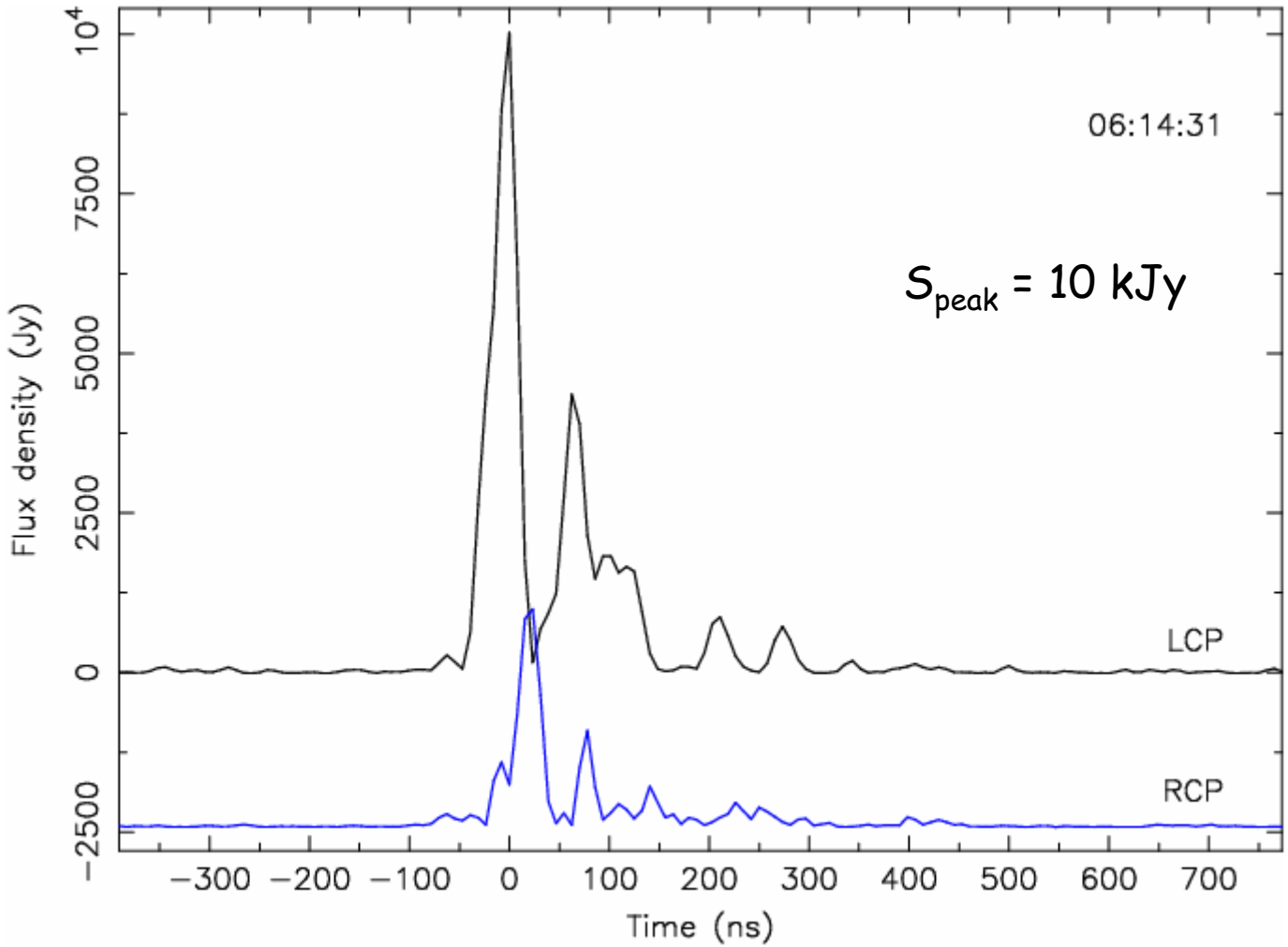
June 6, 2005

Mark5A backend

@ LCP & RCP



Strongest GP



B = 64 MHz

GPs Summary

Time processed ~ 5h30min (total time ~ 7h 30min)

Number of GPs: 6334 (6915 events)
MP = 3234 (51%)
IP = 3100 (49%)

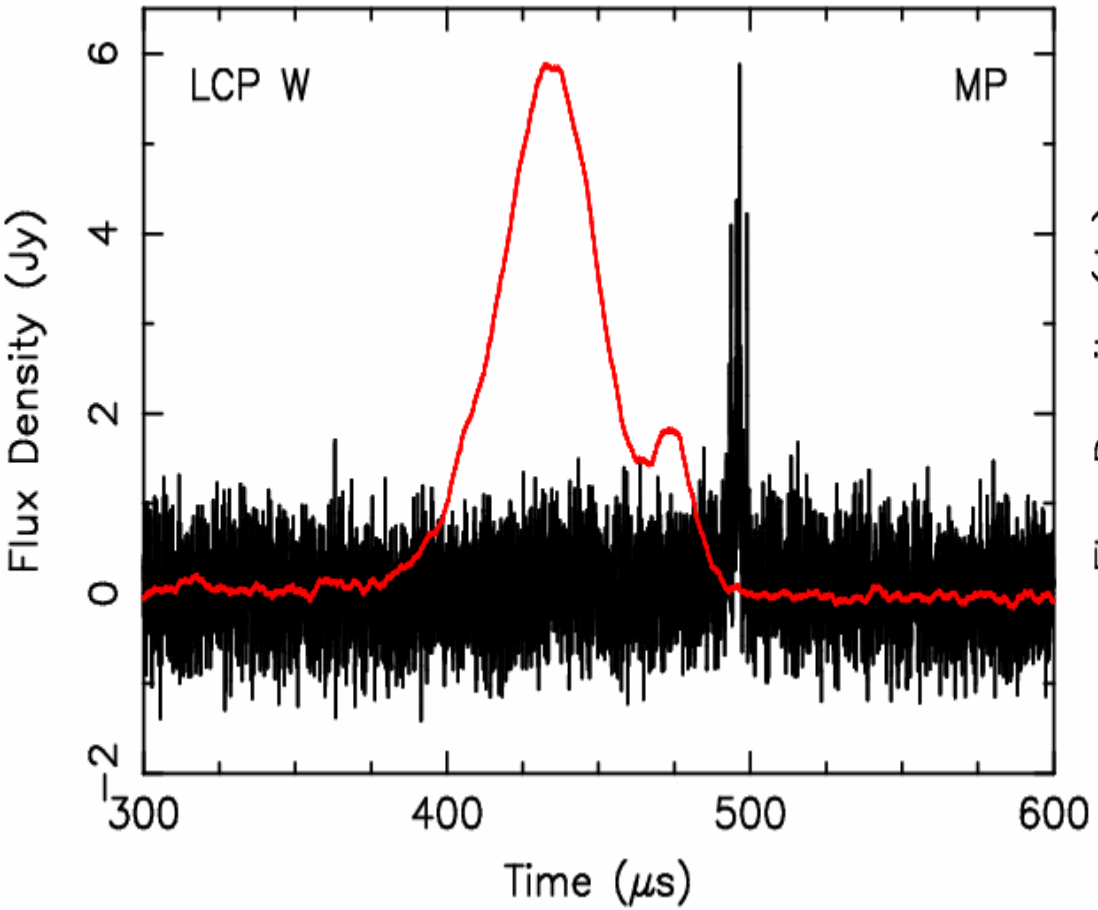
LCP = 3489 (50.4%)
RCP = 3426 (50.6%)

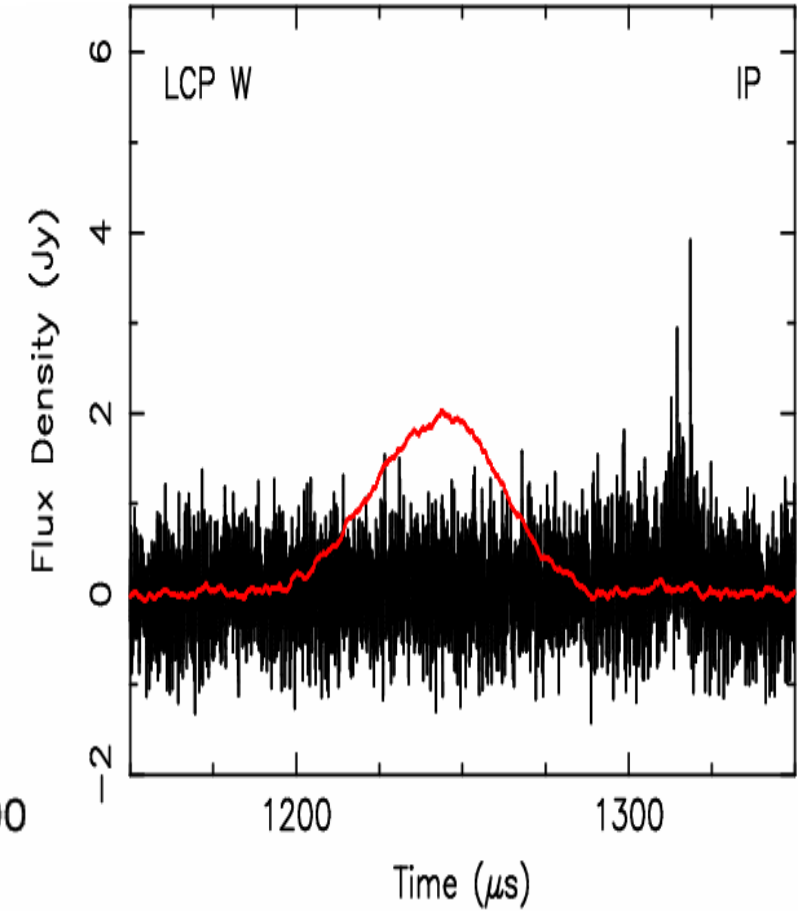
W = 1844 (26.7%)
X = 1796 (26.0%)
Y = 1593 (23.0%)
Z = 1682 (24.3%)

GP rate — $\sigma \geq 20$: 4 GPs/min $\sigma \geq 17$: 20 GPs/min

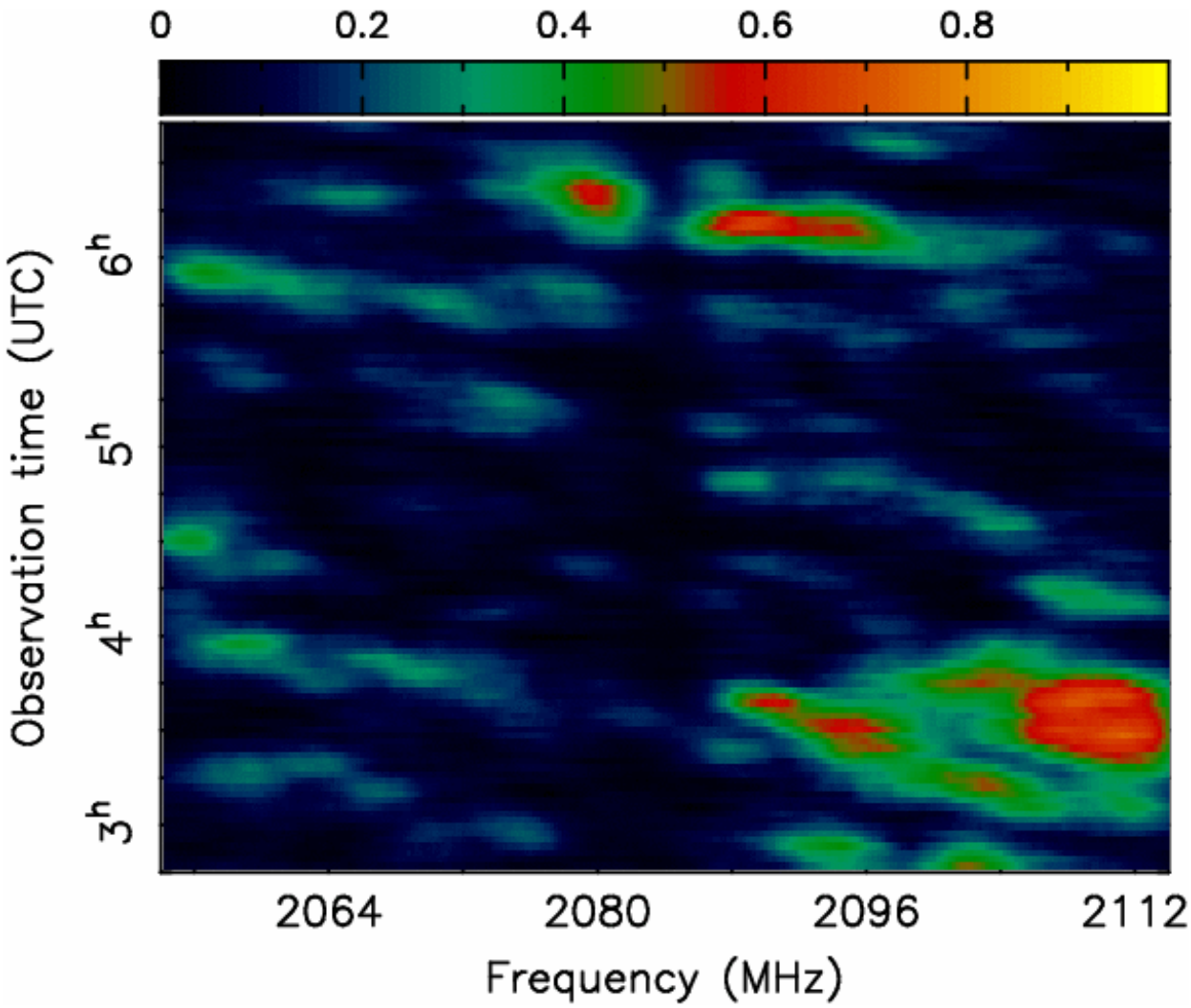
Number of GPs with $\sigma \geq 50$ ($S_{peak} \geq 600$ Jy) = 177

GPs longitudes



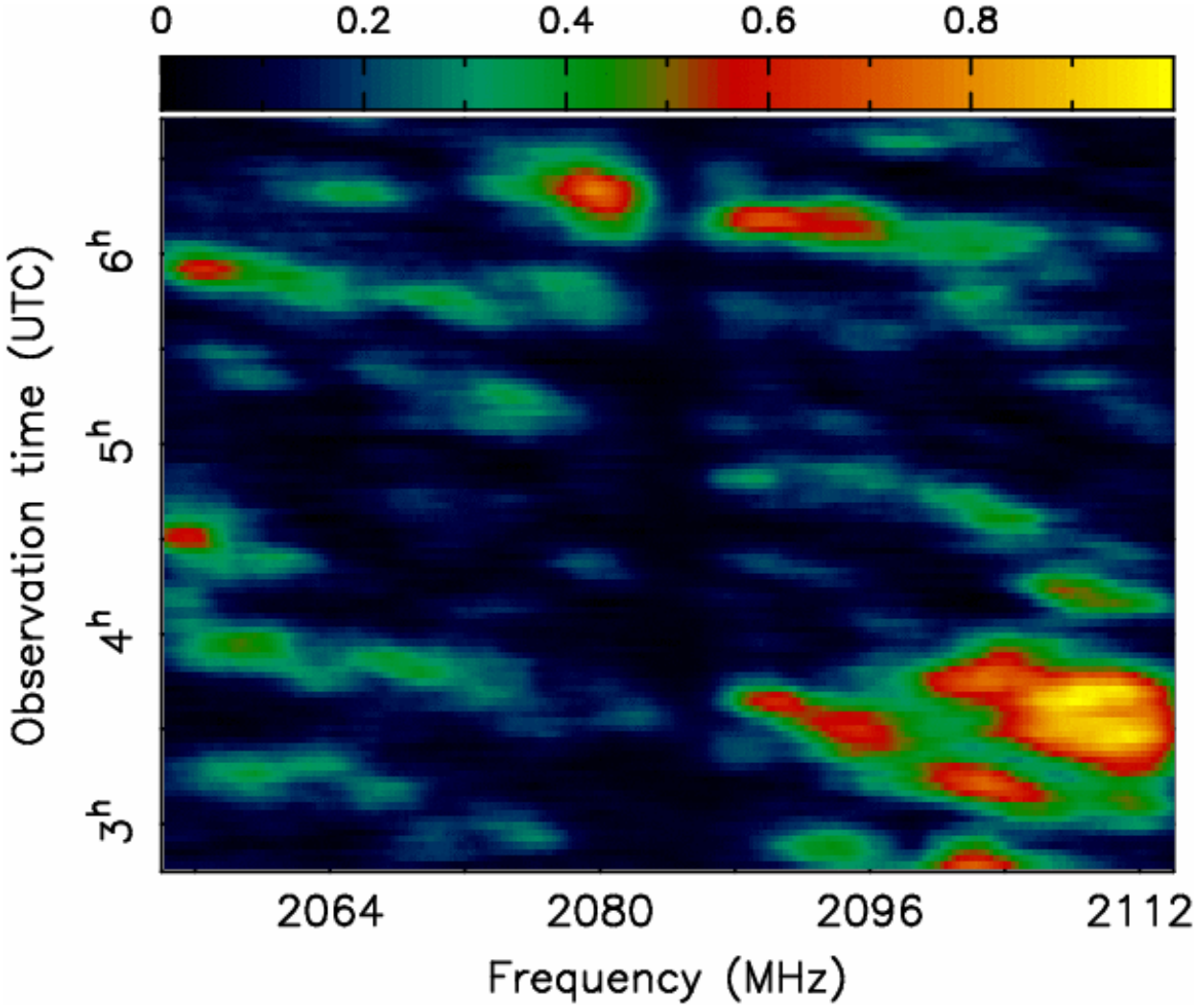


Dynamic spectrum of regular emission



@ RCP

Dynamic spectrum of regular emission

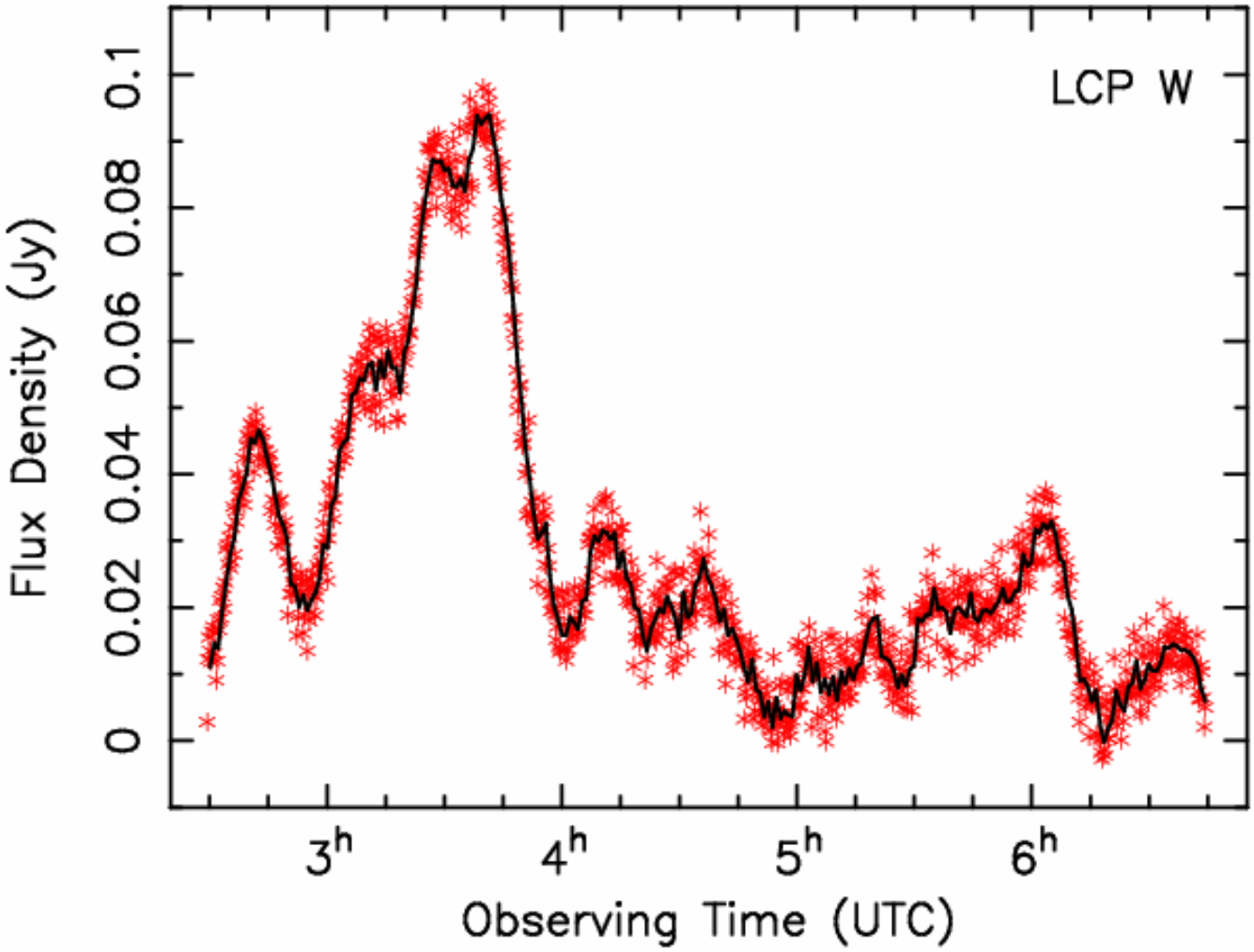


@ LCP

ν_d ~ 8 MHz

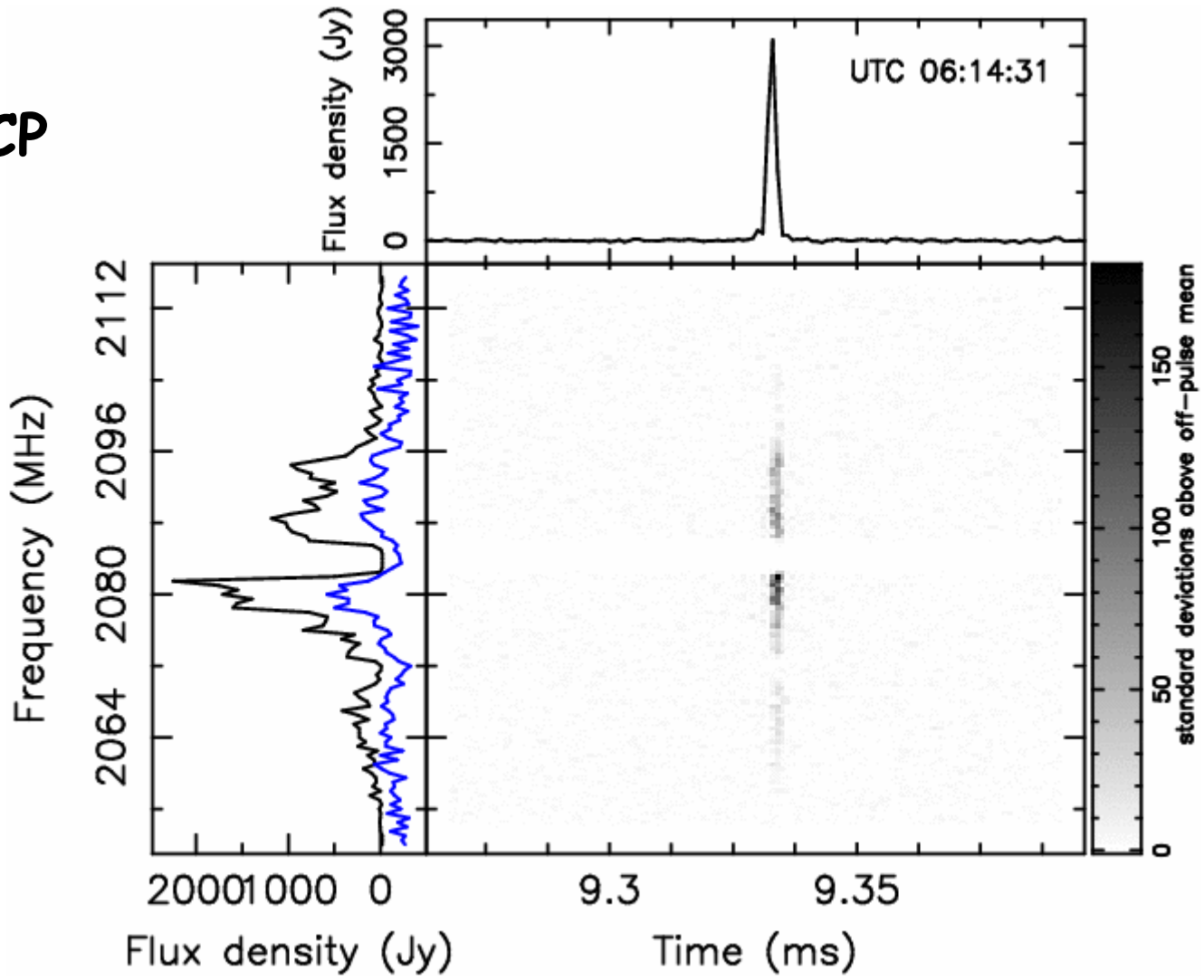
t_{sc} ~ 30 min

Energy fluctuations of regular emission



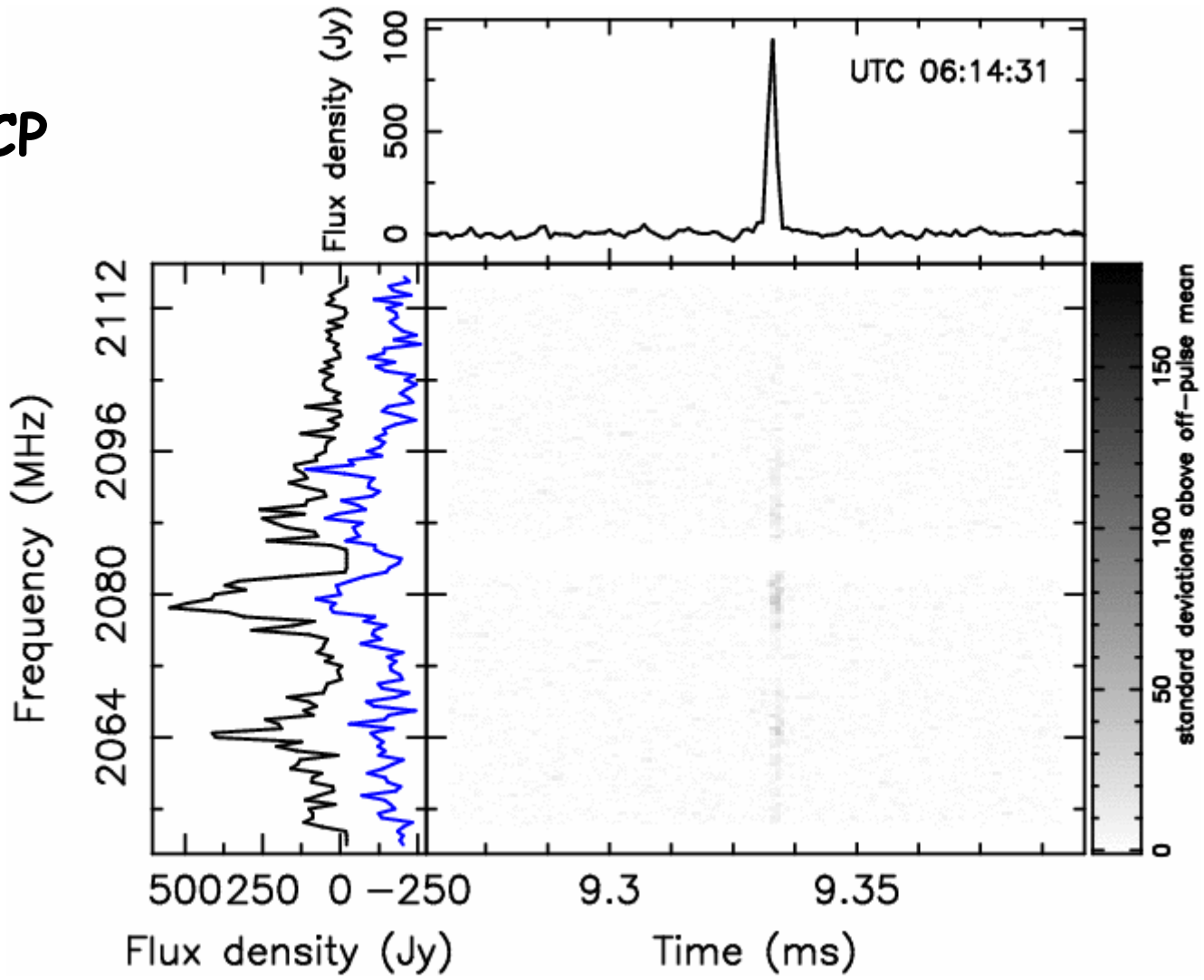
GPs Instant Spectra

LCP

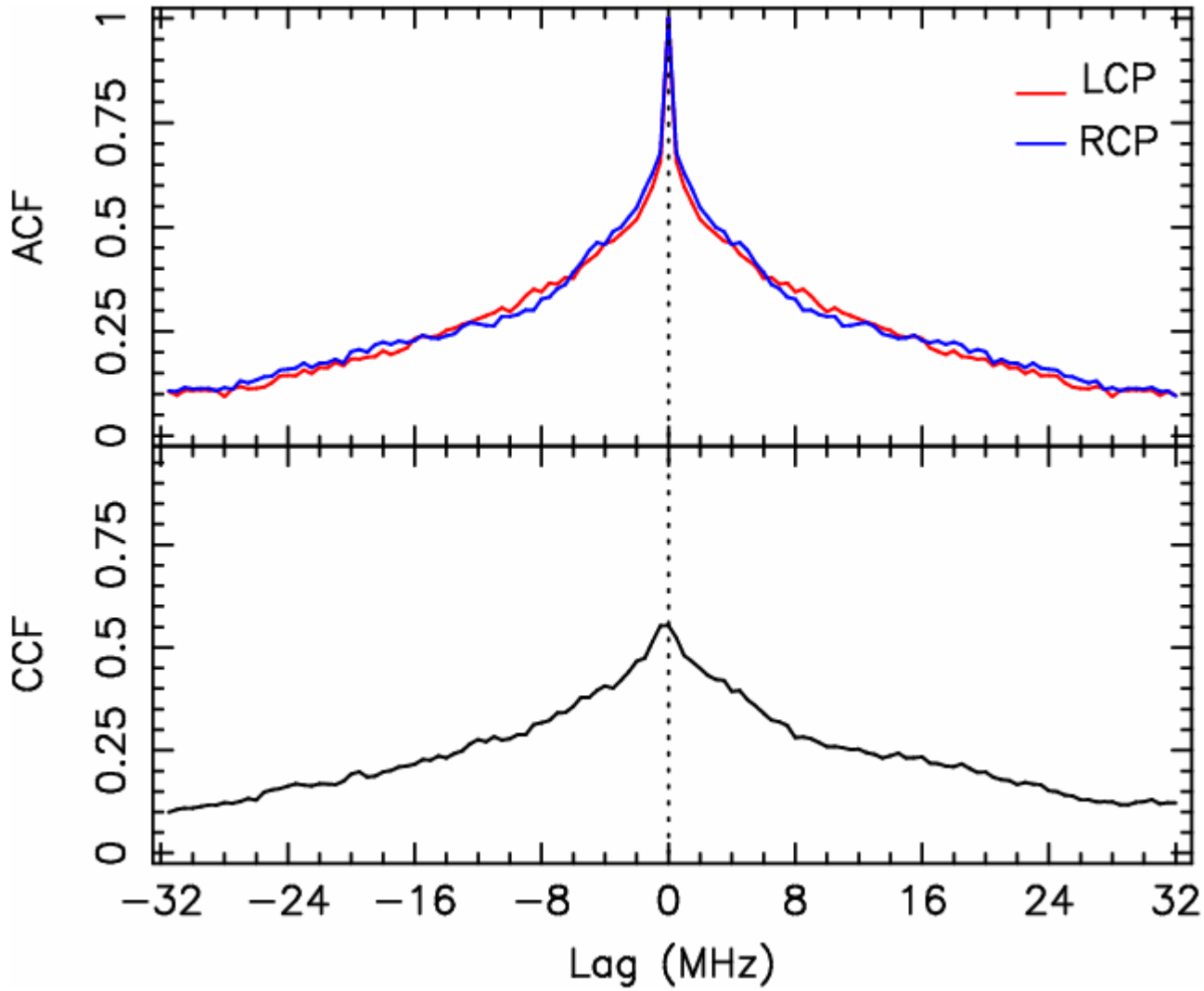


GPs Instant Spectra

RCP



GPs Instant Spectra



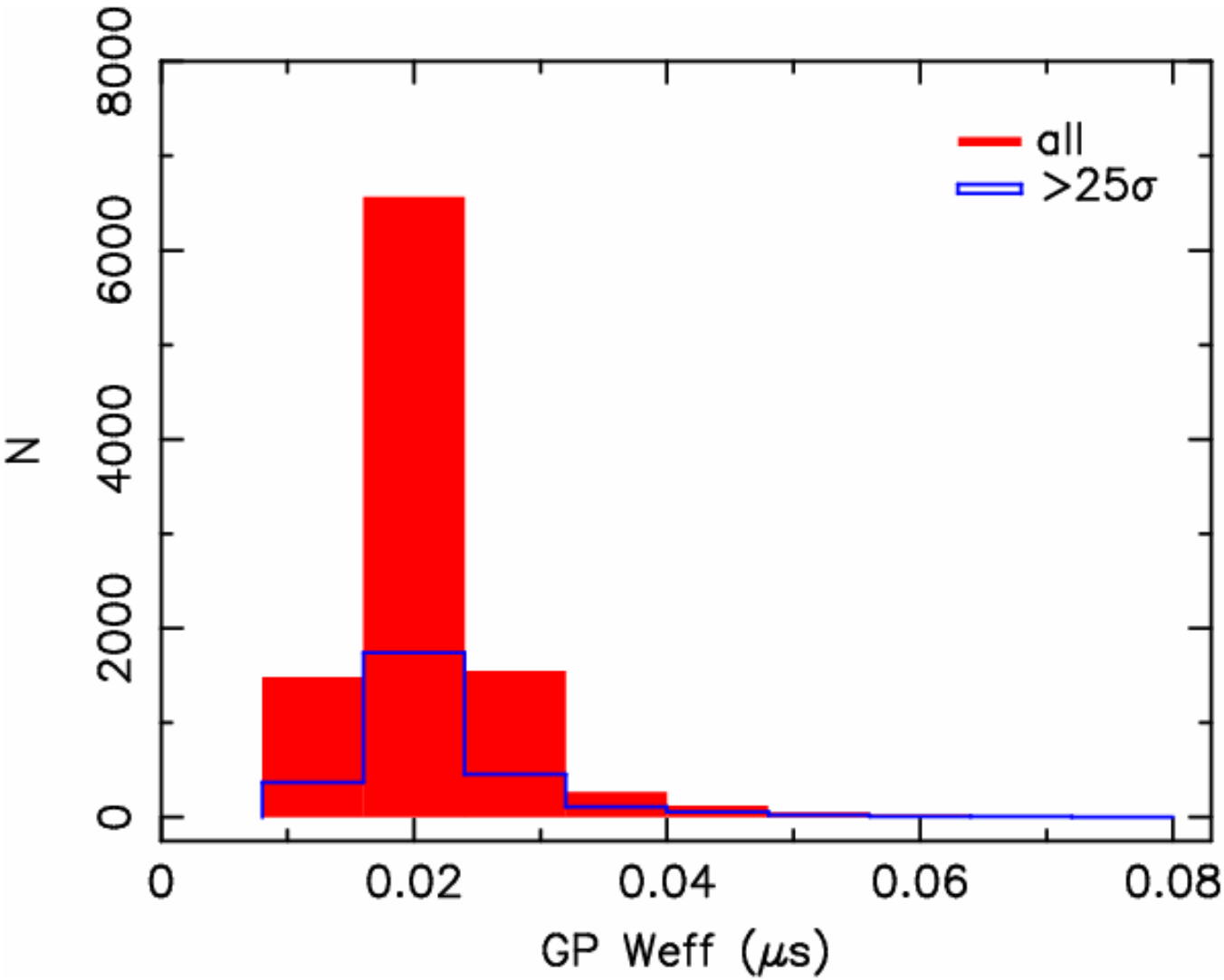
N_{GP} = 22

S_{peak} > 1.2 kJy

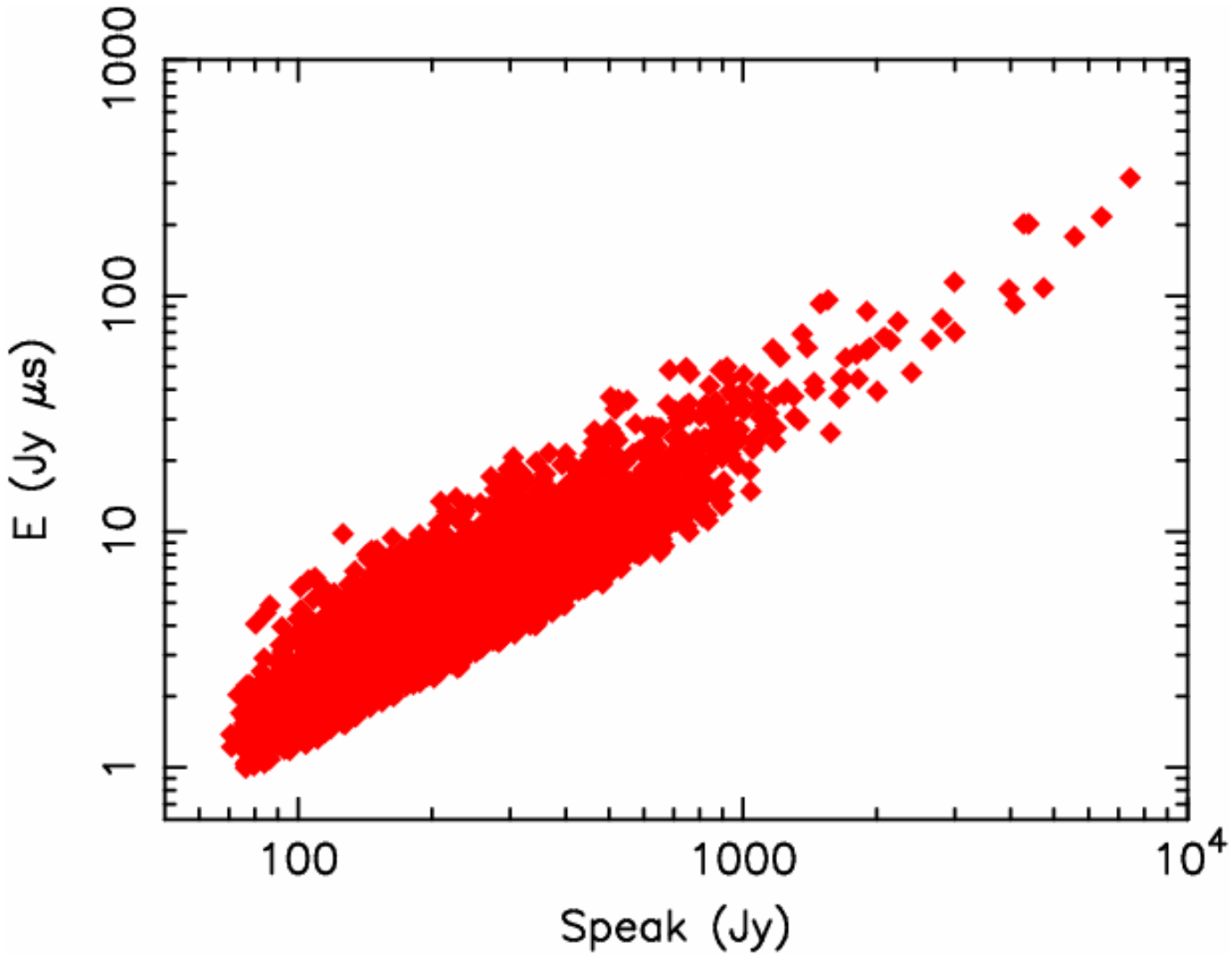
ν_d = 8 MHz

$\tau_{sc} \sim 1/2\pi\nu_d \sim$ 20ns

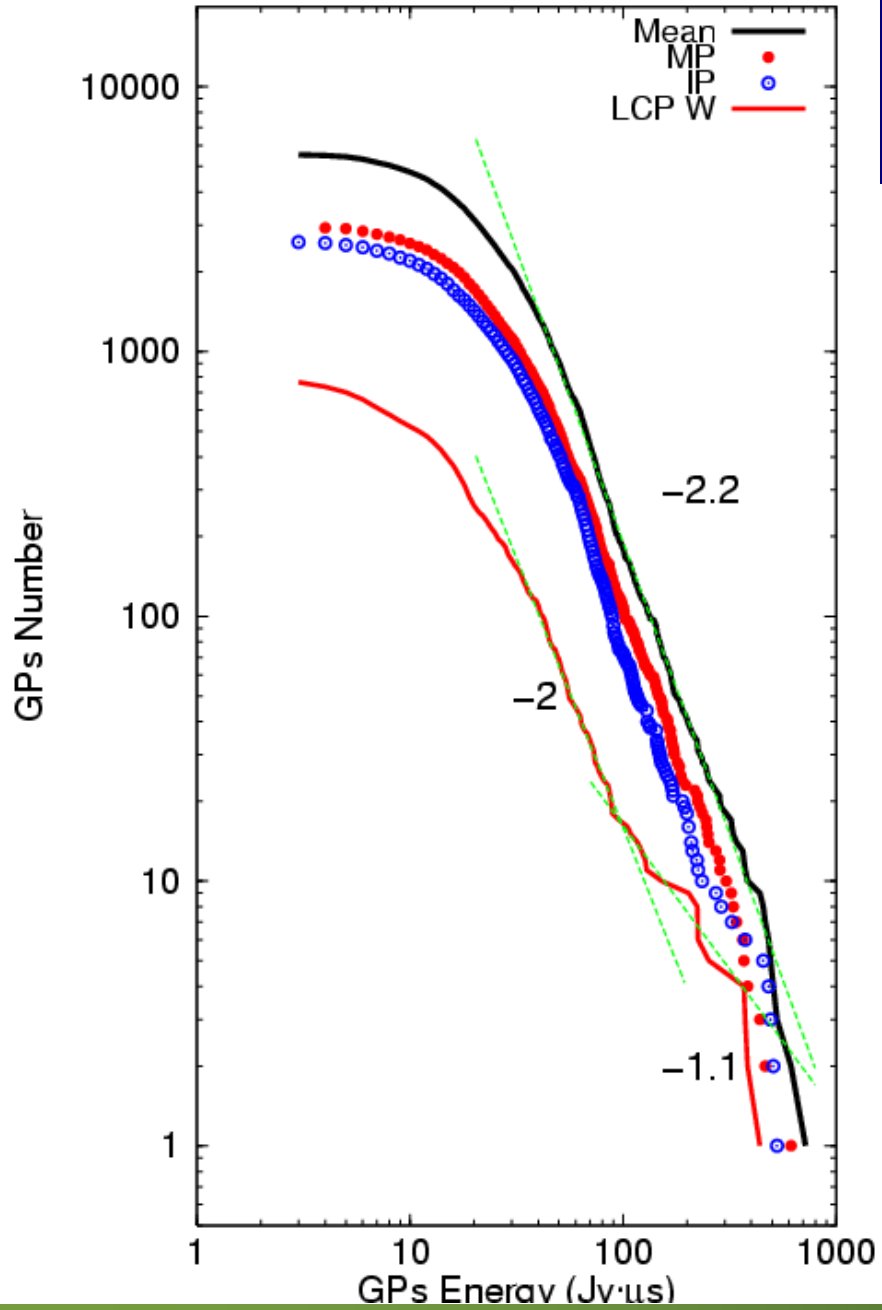
GPs Widths



$E - S_{peak}$

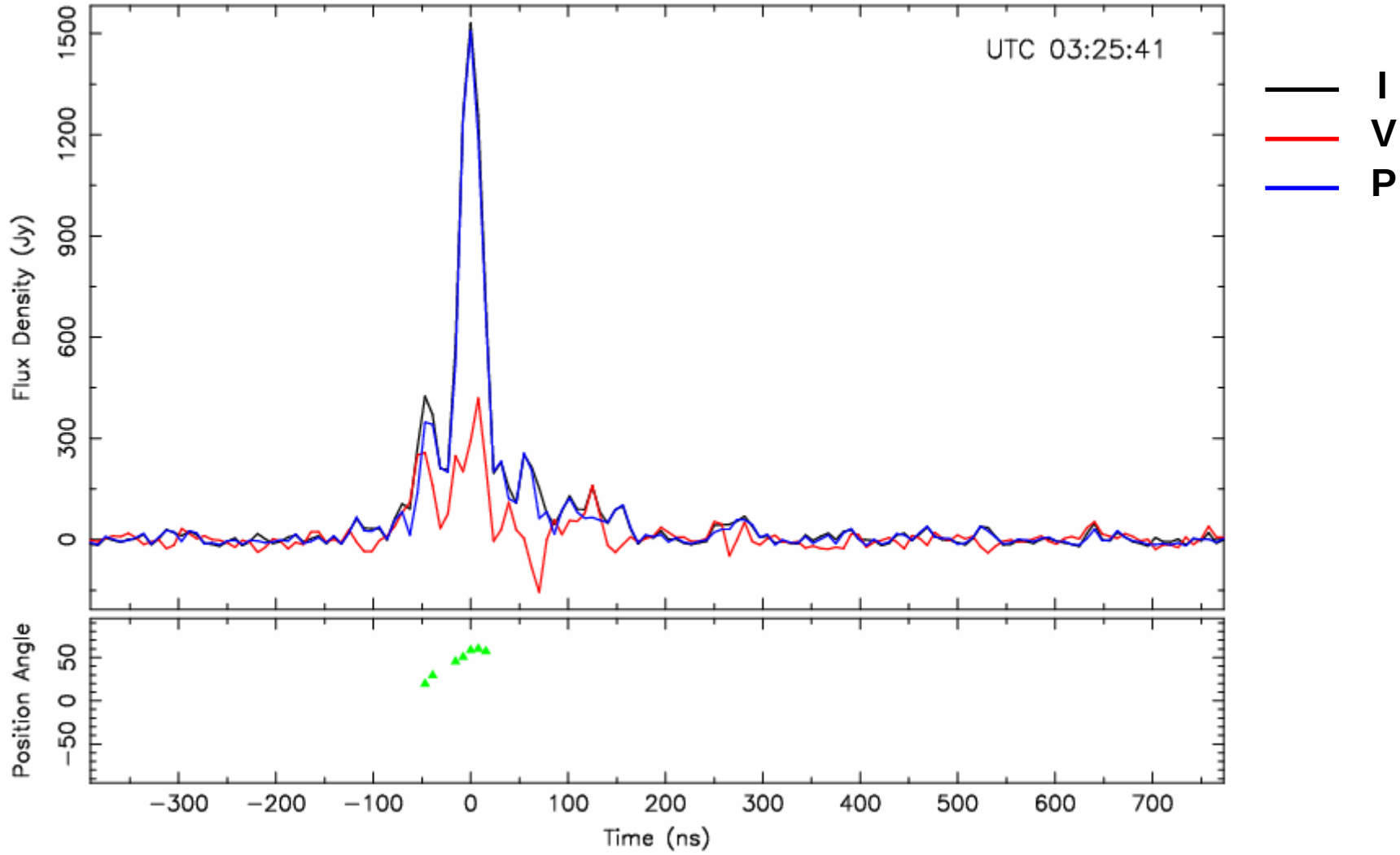


LogN – LogS

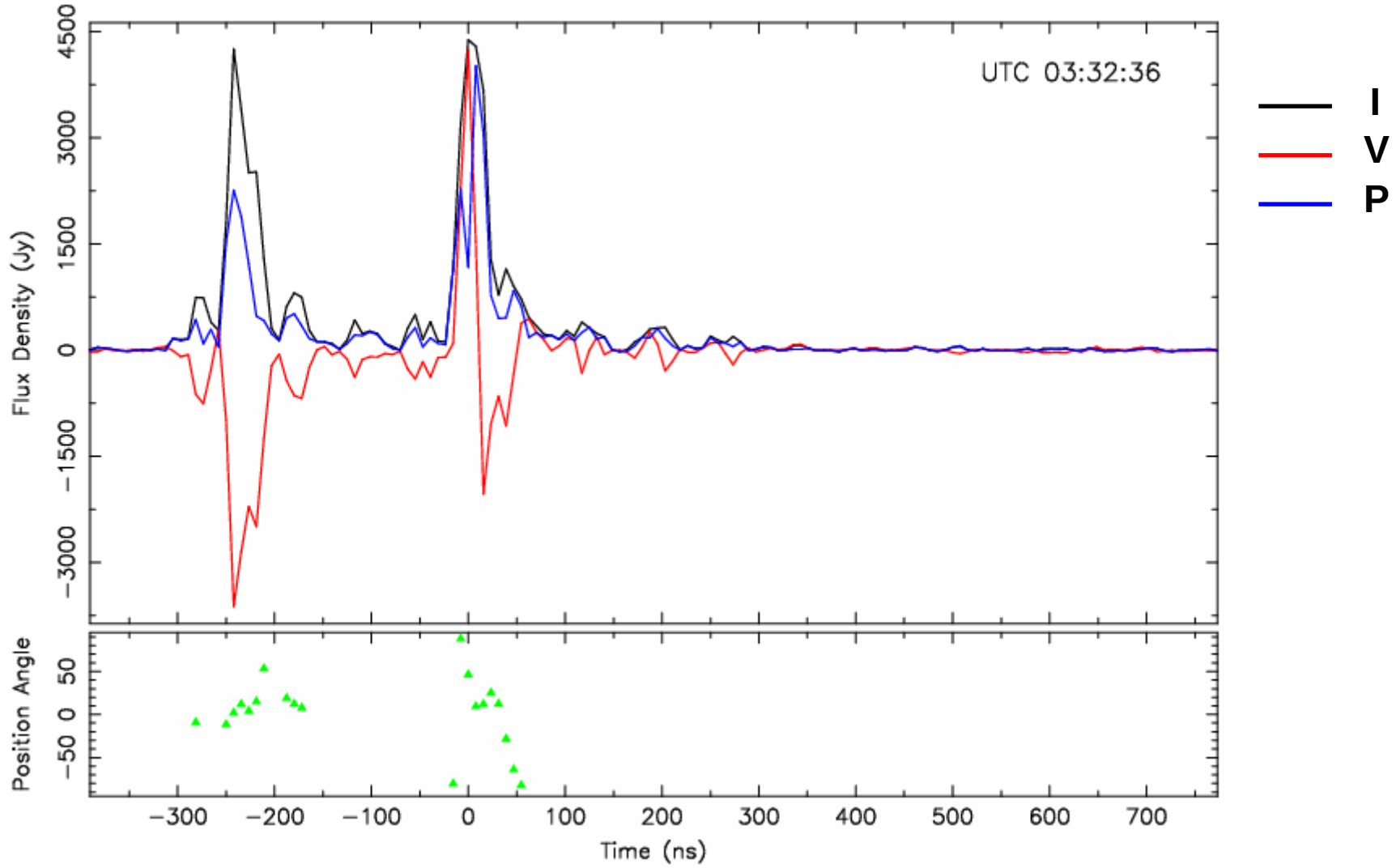


channel	α_1	α_2
LCP W	-2.03±0.02	-1.1±0.1
X	-3.73±0.06	-1.4±0.3
Y	-2.48±0.04	
Z	-2.43±0.02	-1.38±0.01
RCP W	-2.63±0.05	-1.41±0.04
X	-2.22±0.03	
Y	-3.15±0.04	
Z	-2.25±0.02	
Total	-2.20±0.01	

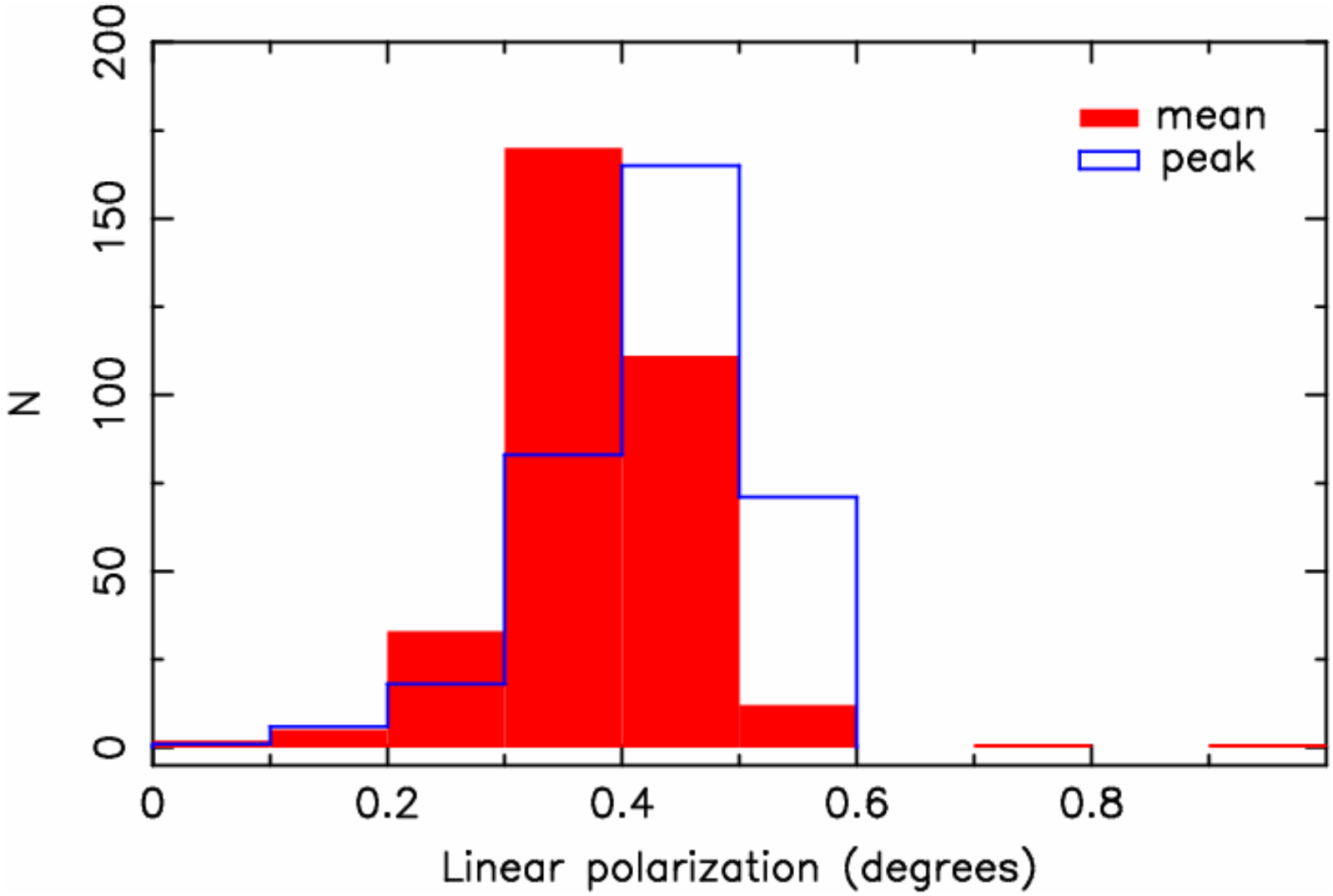
GPs Polarization



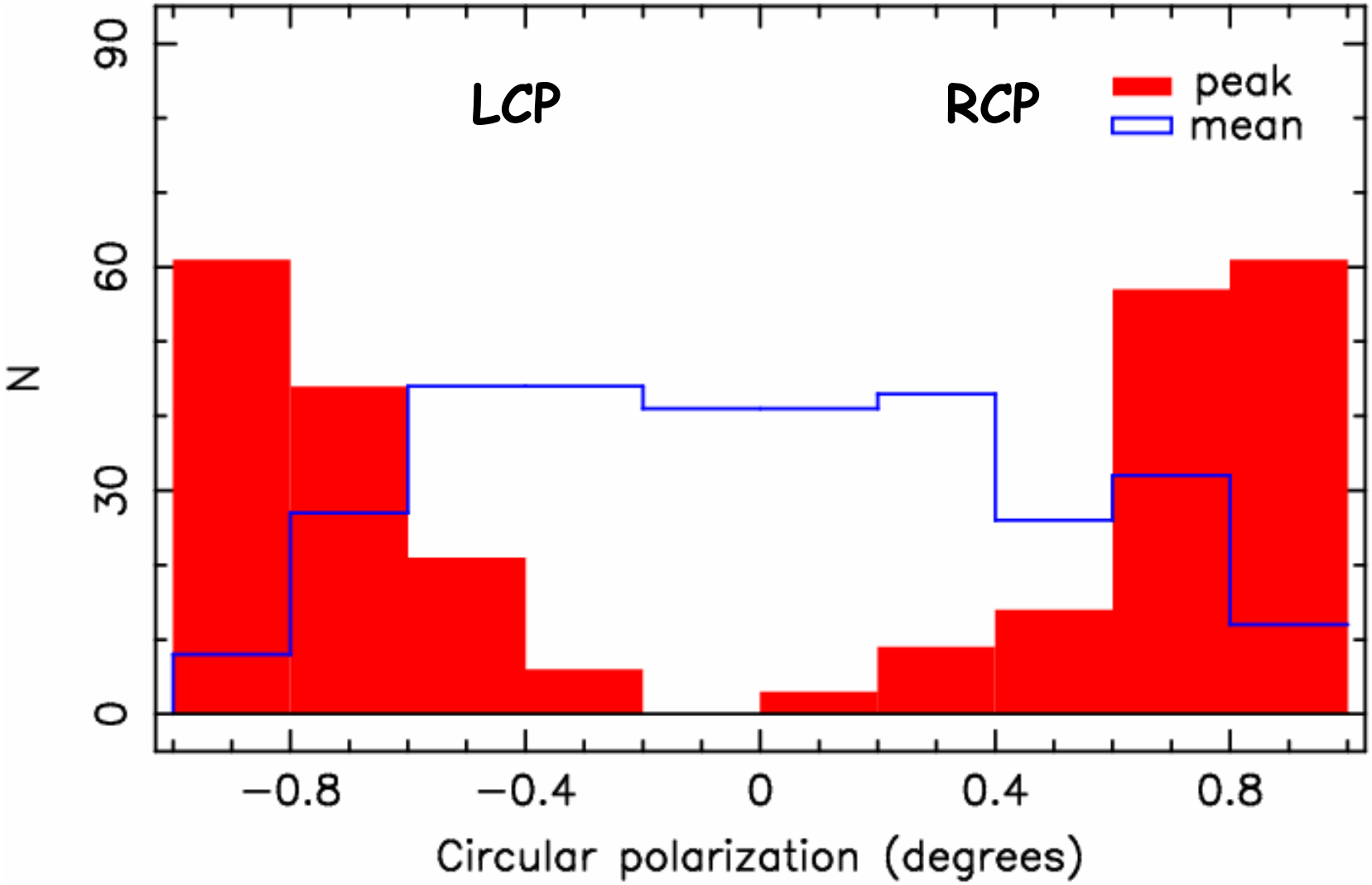
GPs Polarization



GPs Polarization



GPs Polarization



Estimation of brightness temperature of GP emission

Brightness temperature

(Soglasnov et al., 2004, ApJ, 616, 439)

$$T_b = \frac{1}{k}\frac{E_p}{\tau_{GP}}\left(\frac{c}{\nu}\right)^2\left(\frac{L}{d}\right)^2 > \frac{E_p \cdot L^2}{k\nu^2\tau_{GP}^3}$$

k – Boltzmann's constant

E_p – energy of GP

L – distance to the pulsar = 3.6 kpc
(Taylor et al., 1993, ApJS, 88, 529)

τ_{GP} – GP duration

ν – observing frequency

for the strongest GP:

$S_{peak} = 836\sigma = 10000$ Jy

$\tau_{GP} \sim 43$ ns

$E_p \sim 432$ Jy · μs

$\nu = 2100$ MHz

$$T_b > 10^{37}\ K$$

Estimation of the volume density of the GP radiation energy

The volume density of the GP radiation energy

(Soglasnov et al., 2004, ApJ, 616, 439)

$$u_{GP} \approx \frac{E_p \Delta\nu}{W \tau_{GP} c} > E_p \cdot \left(\frac{2\pi L}{P}\right)^2 \frac{\tau_{WGP}^2}{c^3 \tau_{GP}^4}$$

$$W = \left(\frac{d}{L\theta}\right)^2 < \left(\frac{P \tau_{GP} c}{2\pi \tau_{WGP} L}\right)^2$$ - dilution factor

$$\Delta\nu \sim \tau_{GP}^{-1}$$ - GP bandwidth

for the strongest GP:

$u_{GP} > 10^{13}$ erg · cm^{-3}

GP	NS	LC	
10^{13}	$2 \cdot 10^{13}$	$4 \cdot 10^{10}$	plasma
	$7 \cdot 10^{15}$	$4 \cdot 10^{10}$	magnetic field

Conclusions

- *Mark5A recording system was used for the first time in single dish mode in our observations;*
- *GPs shapes are affected by scintillations with scintillation time of ~ 30 min and decorrelation bandwidth of ~ 8 MHz;*
- *Width of the most GPs is of about 20 ns that is the result of scattering;*
- *GPs energies exhibit power-law statistics with the average index of –2.2;*
- *GPs are highly polarized events with polarization degree up to 100% at circular or linear polarization. Mean linear polarization degree is 40%. 75% of GPs have peak circular polarization degree more than 60%;*