Hunting for Pulsars

Agenda

- **Why Pulsars**
- **Methodology to detect Pulsars.**
- **Program to predict Pulsar detectability : MURMUR.**
- **Early detection @ I1NDP and latest developments with wide bandwidth.**
- **Results and detailed analysis of special Pulsars detection @ OE5JFL.**

Mario Armando Natali , I0NAA

I0NAA Mario

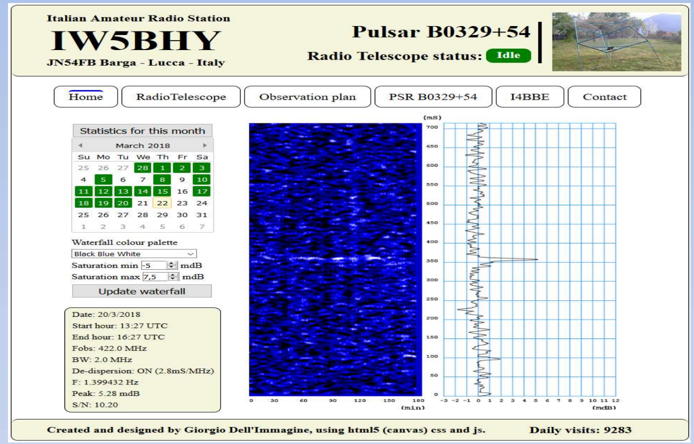
mario.natali@gmail.com

Hunting for Pulsars

Why Pulsars .....

At EME 2016 the detection of pulsars was just a dream, but in less than two years thanks to a strong team effort (IW5BHY, I1NDP, OE5JFL, I0NAA) we have established a methodology that includes peer review. The best performing station has detected more than 50 Pulsars!

The chief enabler for this success was Andrea, IW5BHY who has created a suite of programs that uses popular low cost SDRs such as RTL-SDR and AirSpy. The application can then perform numerical analysis and organize the received data into the ‘filterbank’ format which allows the use of professional radio astronomy programs such as PRESTO, SIGPROC and TEMPO.
Andrea also made his radio telescope available online. It is configured in drift scan and continuously receive the Pulsar B0329+54.



B0329+54 continuous detection @ IW5BHY
http://iw5bhy.altervista.org

It is interesting to note that the vast majority of amateurs that are able to detect Pulsars are also avid EMErs. This is highlighted in Neutron Star Group web site maintained by Steve Olney.
The successful reception of Pulsars requires careful optimisation which in turn improves the effectiveness of an EME station. The requirement to squeeze every single ‘electron’ from the receive set-up allowing results in a truly state-of-the art system.

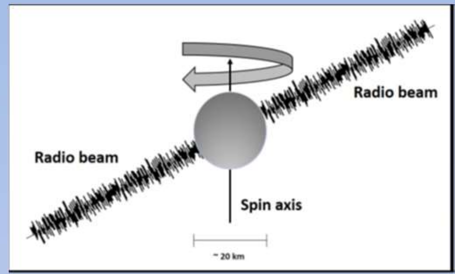
http://neutronstar.joataman.net/ maintained by Steve Olney

Mario Armando Natali , I0NAA

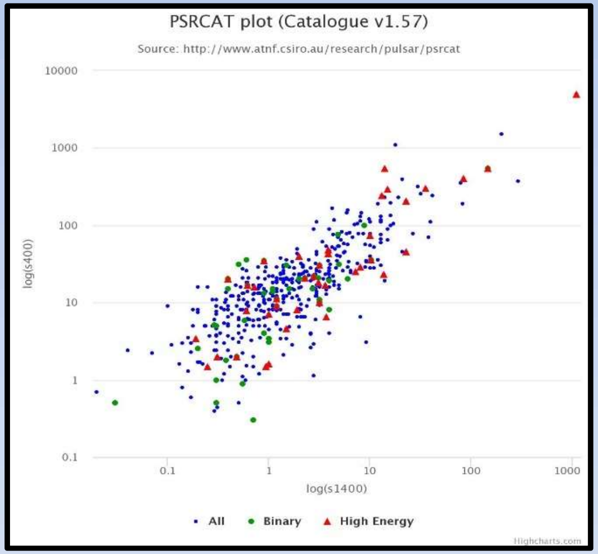
Hunting for Pulsars

Why Pulsars .....

A Pulsar is the remnant of a catastrophic stellar explosion (Supernova) that due to a fortunate sequence of events behaves like a 'cosmic lighthouse'. The resultant noise bursts have a very regular interval. This pulse interval can be from milliseconds to seconds.



Schematic image of a pulsar



Flow @ 400 Mhz vs. flux @ 1400 Mhz extracted from ATNF .

If an observer is lucky and the direction of the 'noise beam' is Earth bound we can then try to detect the Pulsar.

The 'noise spectrum' emitted from the Pulsar is very wide, but it is stronger at lower frequencies (down to a few MHz) and weaker at higher frequencies (in the GHz range).

The 'energy' of the 'noise' signal emitted is VERY LOW and this is the thing that makes this activity both stimulating and interesting!

In radio astronomy the intensity of signals is measured with the concept of 'Flow' due to the intrinsic nature of signals that are wide band and incoherent ; the unit of measure is the 'jansky' or Jy (named after Karl Guthe Jansky who discovered galactic radiation in 1932) and is equal to 10^{-26} W/m^2/Hz.

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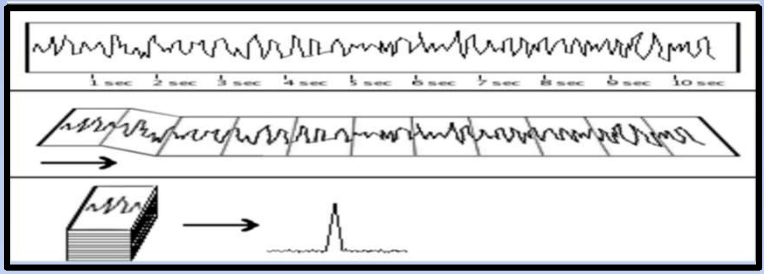
Why Pulsars .....

To put the strength of a Pulsar signal into perspective we can use EME at 1.3GHz as an example: the path loss is approximately 270 dB which means that a 1W EIRP signal will be return to Earth at -240dBm equivalent to 3,000 Jy in a 3 KHz bandwidth.
The strongest Pulsar at 1.4GHz has a Flux intensity of 1 Jy (but all others are in the range of mJy),
The sun has a Flux intensity of 400,000 – 500,000Jy and the moon is approximately 800Jy.

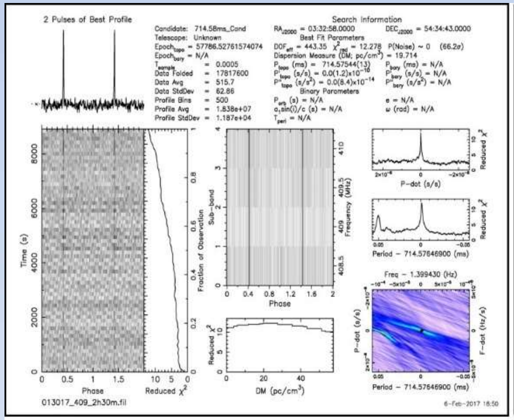


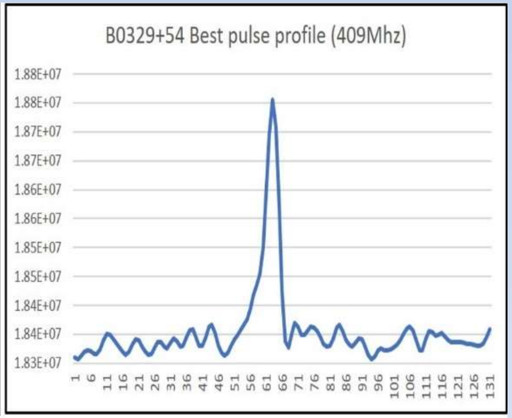
The Folding technique allows to the emitted noise to be summed. The folding must be done EXACTLY at the Pulsar TEMPO

The example above makes it clear that the Pulsar signals cannot be heard with amateur equipment in real time and so it is necessary to make long recording of a large chunk of the RF spectrum (minimum 2 MHz) to collect more 'noise' and perform a numerical analysis 'FOLDING' the received data with the right 'TEMPO'.

Main blocks of an amateur digital Pulsar receiving system

Wide band rx	Digitisation and FFT	Channelization	Numerical analysis
The goal is to receive the max possible bandwidth to collect more 'noise'. Bandwidth is between 2 MHz to 50 MHz obviously more BW = more RFI	Digitisation of the signal and the shift from the time domain to the frequency domain is the key for the subsequent data processing.	The splitting of the total received bandwidth into smaller pieces allows the use of DSP tools such as RFI mitigation.	The data processing is based on some professional software called PRESTO for analysis and on TEMPO for the EXACT determination of the Pulsar period.





Detection details					
Center frequency	Mhz	409	Tsky	K	10
Integration Bandwidth	Mhz	2	Total system noise figure	dB	0.76
Intergration time	s	9120	System MDS	mJy	115.35
Antenna Gain	dB	23	Software for recording		IW5BHY (Windows)
Antenna feeder	type	BFR	Software for analysis		PRESTO (Linux)
Preamplifier NF	dB	0.45	Receiver type		RTL-SDR
Preamplifier Gain	dB	60	GPSDO		NO
Date of detection	30-jan-2017				

PSR Main parameters					
RAJ(hms)	hms	03:32:59.368	DECJ(hms)	hms	+54:34:43.57
RAJD	deg	53.24737	DECJD	deg	54.57877
S400	mJy	1500.0	S1400	mJy	203.0
PO	s	0.7145197	DIST	kpc	1.000
DM	cm^-3 pc	26.7641	DIST (derived)	Light Yr	3261.56
W50	ms	6.6	AGE	Yr	5.53E+06
W10	ms	31.4	AGE (derived)	Million Yr	5.530
Data from ATNF Catalogue ver.1.57					

B0329+54 detection @ I0NAA – 409 Mhz 9120 sec. 2 Mhz BW
http://i0naa.altervista.org

Hunting for Pulsars

Governing equation

- ✓ **Interstellar path loss is much more complex and unpredictable than EME path loss. Also the intermittent pulsed nature of the emitted noise burst makes things even more complicated .**
- ✓ **Fortunately the radiometer equation allows good prediction of the detectability of a Pulsar by comparing station characteristics and Pulsar distinctive elements:**

$$S_{min} = \beta \frac{2k_b(\frac{S}{N}_{min})T_{sys}}{A_e\sqrt{n_p t_{int}\Delta f}} \sqrt{\frac{W}{P-W}}$$

S_{min} ***= Minimum Detectable Signal (Jansky)***

β ***= Factor to take in account system imperfections. >=1 (dimensionless)***
k_b ***= Boltzmann's constant (1.38 * 10^{-38} joule K^{-1})***
A_e ***= Effective aperture of antenna (m^2)***
$\frac{S}{N}_{min}$ ***= Minimum S/N threshold (dimensionless)***
T_{sys} ***= Total system noise temperature (K)***
n_p ***= 1 for single polarization, 2 for two polarizations (dimensionless)***
t_{int} ***= Integration time (sec)***
Δ_f ***= Detection bandwidth (Hz)***
W ***= Pulsar pulse width (msec.)***
P ***= Pulsar pulse period (msec.)***

D. Lorimer, M. Kramer, **Handbook of Pulsar Astronomy**
Cambridge University Press, pp262-265

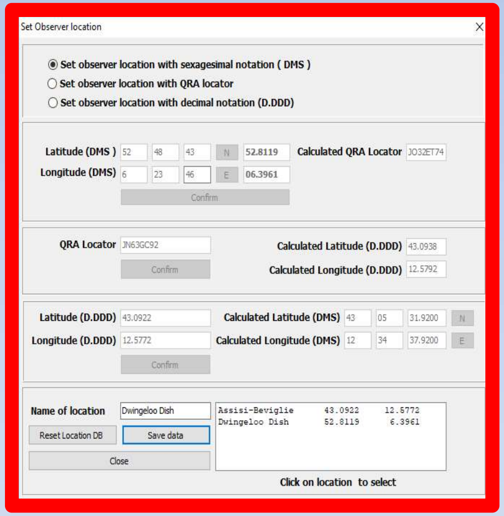
The equation it is not so difficult to calculate, but there are many parameters involved. The program MURMUR provides an automatic solution by just entering basic station parameters.

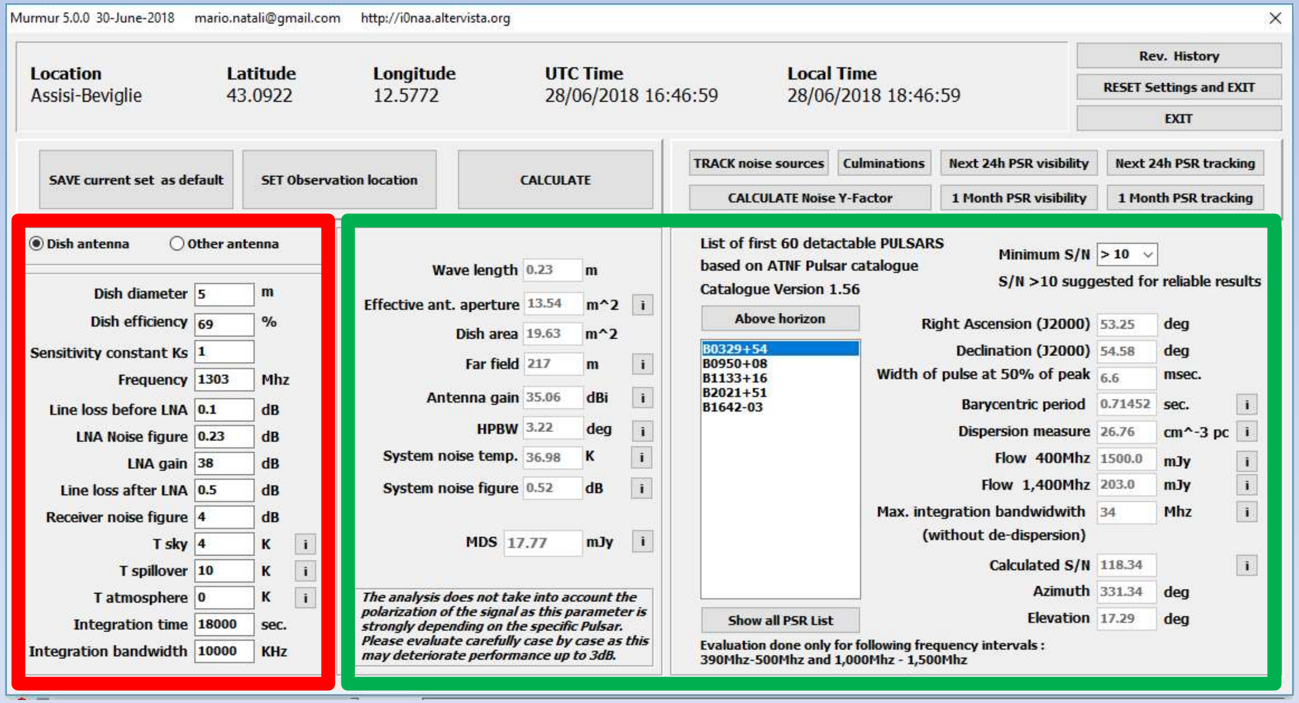
Hunting for Pulsars

Murmur

- ✓ **MURMUR is available from the web site http://i0naa.altervista.org and has an installer that creates a directory used to store configuration and local parameters.**

- ✓ **The program does not touch any register entries and can be completely removed simply deleting the directory .**





Inputs

The data to enter are the basic characterstics of the station and the coordinates of the observation place.

Outputs

Hunting for Pulsars

Murmur

MURMUR also provides real time tracking of the Pulsars under scrutiny as well as the most important radio sources. Additionally the visibility of the Pulsars for the next 24 hours and the next month, the culmination data of the radio sources and a list of the strongest 60 Pulsars (by flow) with the main characteristics .

Noise sources tracking

	Azimuth Deg.	Elevation Deg.
Moon	185.00	62.98
Sun	253.32	18.38
Cygnus A	322.67	6.34
Taurus A	141.79	64.87
Cassiopeia A	317.10	42.37
Sagittarius A	306.17	-68.93
3C273	66.91	-19.98
B0329+54	326.52	75.36

Hide main screen | Exit

Real time Az-El widget

Next 30 culminations - THIS CAN TAKE SOME TIME !

Moon | Sun | Cygnus-A | Taurus-A | Cassiopeia-A | Sagittarius-A | 3C273 | B0329+54

Date Time (UTC)	Date Time (Local)	Azimuth (Deg.)	Elevation (Deg.)
Fri Mar 23 15:03:11 2018	Fri Mar 23 17:03:11 2018	359.91	88.23
Sat Mar 24 14:59:15 2018	Sat Mar 24 16:59:15 2018	359.92	88.23
Sun Mar 25 14:55:19 2018	Sun Mar 25 16:55:19 2018	359.93	88.23
Mon Mar 26 14:51:23 2018	Mon Mar 26 16:51:23 2018	359.93	88.23
Tue Mar 27 14:47:27 2018	Tue Mar 27 16:47:27 2018	359.94	88.23
Wed Mar 28 14:43:31 2018	Wed Mar 28 16:43:31 2018	359.95	88.23
Thu Mar 29 14:39:35 2018	Thu Mar 29 16:39:35 2018	359.96	88.23
Fri Mar 30 14:35:40 2018	Fri Mar 30 16:35:40 2018	359.88	88.23
Sat Mar 31 14:31:44 2018	Sat Mar 31 16:31:44 2018	359.89	88.23
Sun Apr 1 14:27:48 2018	Sun Apr 1 16:27:48 2018	359.90	88.23
Mon Apr 2 14:23:52 2018	Mon Apr 2 16:23:52 2018	359.91	88.23

Next 30 culminations - THIS CAN TAKE SOME TIME !

Moon | Sun | Cygnus-A | Taurus-A | Cassiopeia-A | Sagittarius-A | 3C273 | B0329+54

Date Time (UTC)	Date Time (Local)	Azimuth (Deg.)	Elevation (Deg.)
Fri Mar 23 11:16:24 2018	Fri Mar 23 13:16:24 2018	180.09	48.18
Sat Mar 24 11:16:06 2018	Sat Mar 24 13:16:06 2018	180.09	48.57
Sun Mar 25 11:15:48 2018	Sun Mar 25 13:15:48 2018	180.09	48.96
Mon Mar 26 11:15:30 2018	Mon Mar 26 13:15:30 2018	180.09	49.36
Tue Mar 27 11:15:11 2018	Tue Mar 27 13:15:11 2018	180.09	49.75
Wed Mar 28 11:14:53 2018	Wed Mar 28 13:14:53 2018	180.09	50.14
Thu Mar 29 11:14:35 2018	Thu Mar 29 13:14:35 2018	180.09	50.53
Fri Mar 30 11:14:17 2018	Fri Mar 30 13:14:17 2018	180.09	50.92
Sat Mar 31 11:13:59 2018	Sat Mar 31 13:13:59 2018	180.09	51.30
Sun Apr 1 11:13:51 2018	Sun Apr 1 13:13:51 2018	180.09	51.46
Mon Apr 2 11:13:33 2018	Mon Apr 2 13:13:33 2018	180.09	51.85
Tue Apr 3 11:13:16 2018	Tue Apr 3 13:13:16 2018	180.09	52.23
Wed Apr 4 11:12:58 2018	Wed Apr 4 13:12:58 2018	180.09	52.61
Thu Apr 5 11:12:41 2018	Thu Apr 5 13:12:41 2018	180.09	52.99
Fri Apr 6 11:12:23 2018	Fri Apr 6 13:12:23 2018	180.09	53.37
Sat Apr 7 11:12:06 2018	Sat Apr 7 13:12:06 2018	180.09	53.75
Sun Apr 8 11:11:49 2018	Sun Apr 8 13:11:49 2018	180.09	54.12
Mon Apr 9 11:11:33 2018	Mon Apr 9 13:11:33 2018	180.09	54.50
Tue Apr 10 11:11:16 2018	Tue Apr 10 13:11:16 2018	180.09	54.87
Wed Apr 11 11:11:00 2018	Wed Apr 11 13:11:00 2018	180.09	55.24
Thu Apr 12 11:10:44 2018	Thu Apr 12 13:10:44 2018	180.08	55.60
Fri Apr 13 11:10:29 2018	Fri Apr 13 13:10:29 2018	180.09	55.97
Sat Apr 14 11:10:14 2018	Sat Apr 14 13:10:14 2018	180.09	56.33
Sun Apr 15 11:09:59 2018	Sun Apr 15 13:09:59 2018	180.09	56.69
Mon Apr 16 11:09:44 2018	Mon Apr 16 13:09:44 2018	180.08	57.04
Tue Apr 17 11:09:30 2018	Tue Apr 17 13:09:30 2018	180.09	57.39
Wed Apr 18 11:09:16 2018	Wed Apr 18 13:09:16 2018	180.08	57.74
Thu Apr 19 11:09:03 2018	Thu Apr 19 13:09:03 2018	180.08	58.09
Fri Apr 20 11:08:50 2018	Fri Apr 20 13:08:50 2018	180.08	58.44
Sat Apr 21 11:08:37 2018	Sat Apr 21 13:08:37 2018	180.08	58.78

Hide main screen | Exit

Culmination data for Sun and for B0329+54

1 Month Pulsar visibility

1 Month Pulsar visibility : B0329+54

Date Time (UTC)	Date Time (Local)	Azimuth (Deg.)	Elevation (Deg.)
Thu Mar 22 15:46:32 2018	Thu Mar 22 17:46:32 2018	290.74	83.89
Thu Mar 22 16:46:32 2018	Thu Mar 22 18:46:32 2018	286.82	75.22
Thu Mar 22 17:46:32 2018	Thu Mar 22 19:46:32 2018	290.43	66.59
Thu Mar 22 18:46:32 2018	Thu Mar 22 20:46:32 2018	295.63	58.22
Thu Mar 22 19:46:32 2018	Thu Mar 22 21:46:32 2018	301.59	50.24
Thu Mar 22 20:46:32 2018	Thu Mar 22 22:46:32 2018	308.12	42.78
Thu Mar 22 21:46:32 2018	Thu Mar 22 23:46:32 2018	315.16	35.99
Thu Mar 22 22:46:32 2018	Fri Mar 23 00:46:32 2018	322.72	30.01
Thu Mar 22 23:46:32 2018	Fri Mar 23 01:46:32 2018	330.76	25.03
Fri Mar 23 00:46:32 2018	Fri Mar 23 02:46:32 2018	339.25	21.18
Fri Mar 23 01:46:32 2018	Fri Mar 23 03:46:32 2018	348.10	18.63
Fri Mar 23 02:46:32 2018	Fri Mar 2		
Fri Mar 23 03:46:32 2018	Fri Mar 2		
Fri Mar 23 04:46:32 2018	Fri Mar 2		
Fri Mar 23 05:46:32 2018	Fri Mar 2		
Fri Mar 23 06:46:32 2018	Fri Mar 2		
Fri Mar 23 07:46:32 2018	Fri Mar 2		
Fri Mar 23 08:46:32 2018	Fri Mar 2		
Fri Mar 23 09:46:32 2018	Fri Mar 2		
Fri Mar 23 10:46:32 2018	Fri Mar 2		
Fri Mar 23 11:46:32 2018	Fri Mar 2		
Fri Mar 23 12:46:32 2018	Fri Mar 2		
Fri Mar 23 13:46:32 2018	Fri Mar 2		
Fri Mar 23 14:46:32 2018	Fri Mar 2		
Fri Mar 23 15:46:32 2018	Fri Mar 2		
Fri Mar 23 16:46:32 2018	Fri Mar 2		
Fri Mar 23 17:46:32 2018	Fri Mar 2		
Fri Mar 23 18:46:32 2018	Fri Mar 2		
Fri Mar 23 19:46:32 2018	Fri Mar 2		
Fri Mar 23 20:46:32 2018	Fri Mar 2		
Fri Mar 23 21:46:32 2018	Fri Mar 2		
Fri Mar 23 22:46:32 2018	Sat Mar 2		
Fri Mar 23 23:46:32 2018	Sat Mar 2		
Sat Mar 24 00:46:32 2018	Sat Mar 2		

Hide main s

B0399+54 visibility

Pulsar list derived from ATNF Catalogue http://www.atnf.csiro.au/research/pulsar/psrcat/

Sorted by S1400 22/03/2018 17:37:45 Local Time

Recalculate | Return to main screen

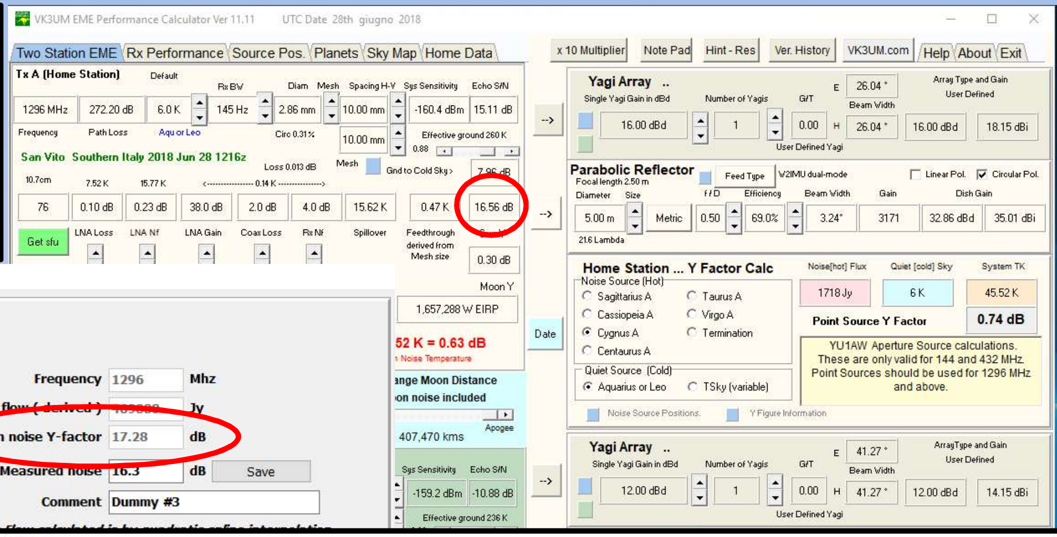
PSR #	PSR name	RA(Deg)	DEC(Deg)	DM(cm^-3 pc)	W50(ms)	S400(mJy)	S1400(mJy)	Barycentric Period(sec.)	Azimuth	Elevation	Visible
0	B0833-45	128.8359	-45.1763	67.990	2.100	5000.0	1100.0	0.08932839	140.46	-13.74	no
1	B1641-45	251.2053	-45.9860	478.800	8.200	375.0	296.4	0.45505978	220.94	-86.09	no
2	B0329+54	53.2474	54.5788	26.764	6.600	1500.0	203.0	0.71451970	325.94	75.22	YES
3	J0437-4715	69.3162	-47.2525	2.645	0.141	550.0	149.0	0.00575745	178.78	-0.36	no
4	B0950+08	148.2888	7.9266	2.969	9.500	400.0	84.0	0.25306516	90.46	12.14	YES
5	B0736-40	114.6347	-40.7114	160.800	29.000	190.0	83.7	0.37491999	146.17	-3.95	no
6	B1451-68	224.0007	-68.7276	8.600	12.500	350.0	80.0	0.26337681	162.28	-61.59	no
7	B1933+16	293.9493	16.2778	158.521	9.000	242.0	42.0	0.35873841	313.36	-16.96	no
8	B1556-44	239.9230	-44.6461	56.100	6.000	110.0	40.0	0.25705610	108.45	-84.31	no
9	B2020+28	305.6544	28.9064	24.631	12.000	71.0	38.0	0.34340216	311.97	-0.42	no
10	B1929+10	293.0581	10.9923	3.183	7.400	303.0	36.0	0.22651764	311.00	-21.83	no
11	B1133+16	174.0135	15.8512	4.841	31.700	257.0	32.0	1.18791307	67.29	-0.73	no
12	B2016+28	304.5160	28.6651	14.198	14.900	314.0	30.0	0.55795348	312.61	-1.22	no
13	B2021+51	305.7078	51.9139	22.550	7.400	77.0	27.0	0.52919692	326.67	17.47	YES
14	B0355+54	59.7238	54.2205	57.142	3.900	46.0	23.0	0.15638412	338.04	77.75	YES
15	B0628-28	97.7058	-28.5785	34.425	58.200	206.0	23.0	1.24441860	153.04	13.15	YES
16	B1054-62	164.1065	-62.9799	320.300	20.000	45.0	21.0	0.42244719	143.73	-40.29	no
17	B1642-03	251.2585	-3.2995	35.756	4.200	393.0	21.0	0.38768970	354.18	-50.07	no
18	B2111+46	318.3514	46.7358	141.260	32.100	230.0	19.0	1.01468479	316.64	19.46	YES
19	B1749-28	268.2445	-28.1104	50.372	9.100	1100.0	18.0	0.56255764	305.12	-67.57	no
20	B2154+40	329.2577	40.2961	71.124	38.600	105.0	17.0	1.52526563	305.94	21.21	YES
21	B1557-50	240.2210	-50.7392	260.560	5.400	0.0	17.0	0.19260123	149.51	-80.88	no
22	B1648-42	252.9533	-42.7697	482.000	110.000	100.0	16.0	0.84408067	272.78	-86.01	no
23	B1323-62	201.8225	-62.3791	318.800	11.000	135.0	16.0	0.52991319	142.07	-57.33	no
24	B0835-41	129.3383	-41.5873	147.290	8.900	197.0	16.0	0.75162362	137.76	-11.27	no
25	B1804-08	271.9085	-8.7953	112.380	8.900	65.0	15.0	0.16372737	320.96	-49.62	no
26	B2310+42	348.2859	42.8870	17.277	8.800	89.0	15.0	0.34943368	299.27	34.39	YES
27	B0740-28	115.7044	-28.3788	73.782	5.400	296.0	15.0	0.16676229	138.76	5.95	YES
28	B0403-76	60.4653	-76.1372	21.600	18.000	19.0	14.0	0.54525274	181.93	-29.32	no
29	B1449-64	223.3864	-64.2210	71.070	4.400	230.0	14.0	0.17948475	155.29	-64.82	no
30	B0531+21	83.6332	22.0145	56.771	3.000	550.0	14.0	0.03339241	142.46	65.03	YES
31	B1800-21	270.9642	-21.6187	233.990	14.000	23.0	13.9	0.13366692	310.30	-60.99	no

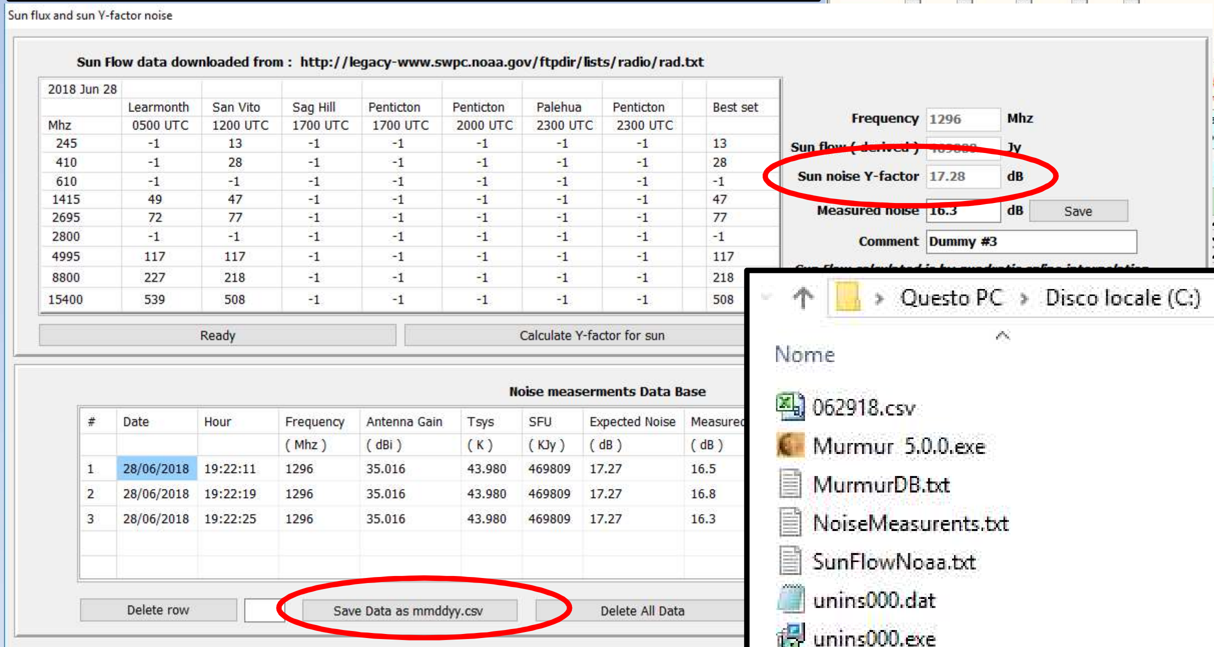
MURMUR internal Pulsar data based on ATNF catalogue

Hunting for Pulsars

Murmur

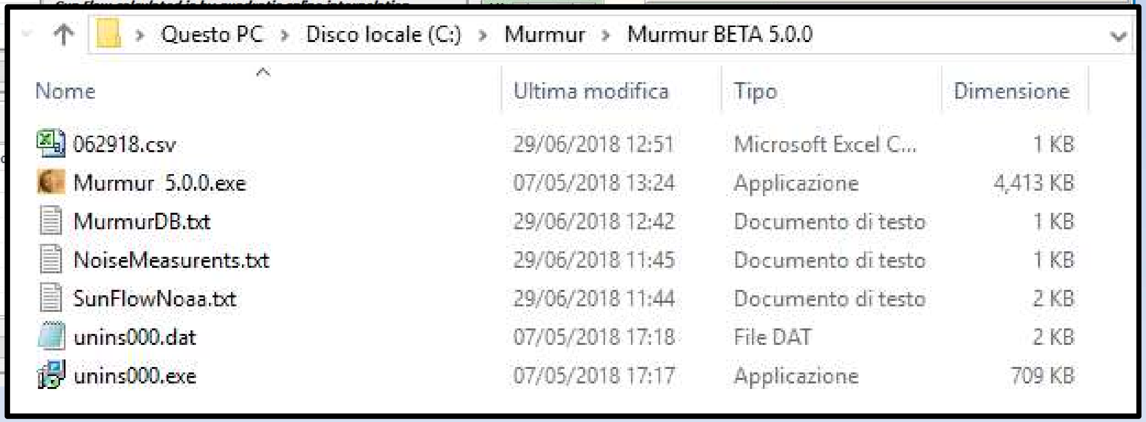
The latest addition to the program is the possibility to predict the sun noise (Y-factor) using quadratic spline interpolation of the solar flux data disseminated from NOAA.





Mhz	Learmonth 0500 UTC	San Vito 1200 UTC	Sag Hill 1700 UTC	Penticton 1700 UTC	Penticton 2000 UTC	Palehua 2300 UTC	Penticton 2300 UTC	Best set
245	-1	13	-1	-1	-1	-1	-1	13
410	-1	28	-1	-1	-1	-1	-1	28
610	-1	-1	-1	-1	-1	-1	-1	-1
1415	49	47	-1	-1	-1	-1	-1	47
2695	72	77	-1	-1	-1	-1	-1	77
2800	-1	-1	-1	-1	-1	-1	-1	-1
4995	117	117	-1	-1	-1	-1	-1	117
8800	227	218	-1	-1	-1	-1	-1	218
15400	539	508	-1	-1	-1	-1	-1	508

#	Date	Hour	Frequency (Mhz)	Antenna Gain (dBi)	Tsys (K)	SFU (KJy)	Expected Noise (dB)	Measured (dB)
1	28/06/2018	19:22:11	1296	35.016	43.980	469809	17.27	16.5
2	28/06/2018	19:22:19	1296	35.016	43.980	469809	17.27	16.8
3	28/06/2018	19:22:25	1296	35.016	43.980	469809	17.27	16.3

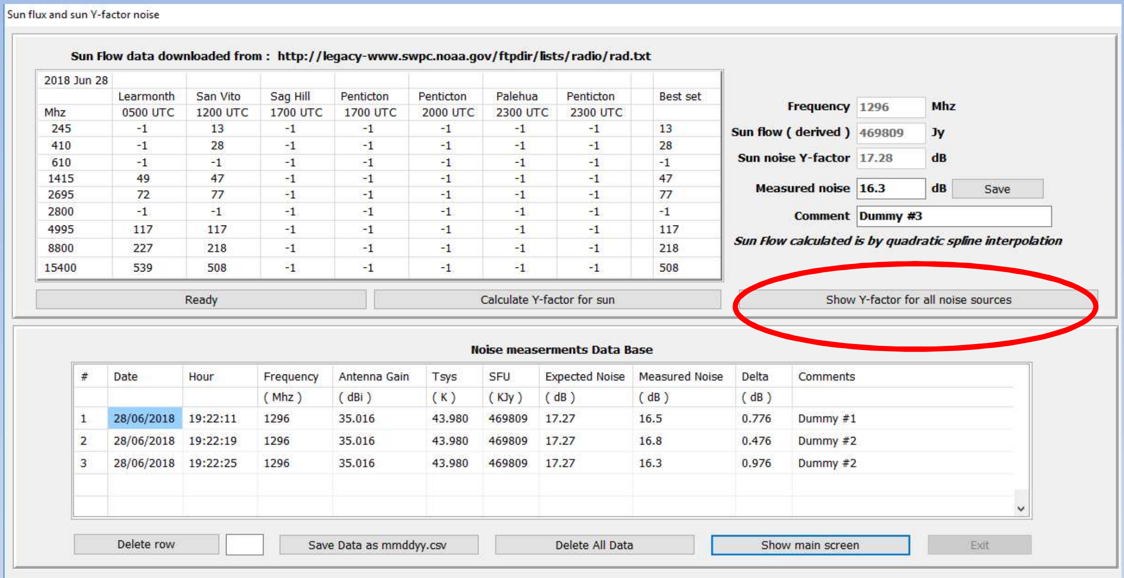


Nome	Ultima modifica	Tipo	Dimensione
062918.csv	29/06/2018 12:51	Microsoft Excel C...	1 KB
Murmur 5.0.0.exe	07/05/2018 13:24	Applicazione	4,413 KB
MurmurDB.txt	29/06/2018 12:42	Documento di testo	1 KB
NoiseMeasurents.txt	29/06/2018 11:45	Documento di testo	1 KB
SunFlowNoaa.txt	29/06/2018 11:44	Documento di testo	2 KB
unins000.dat	07/05/2018 17:18	File DAT	2 KB
unins000.exe	07/05/2018 17:17	Applicazione	709 KB

- ✓ **Sun noise predictions have been verified as accurate and results closely agree with those from the VK3UM EME performance calculator.**
- ✓ **The ability to record and export field measurements and program predictions is a very useful tool to track station performance!**

Hunting for Pulsars

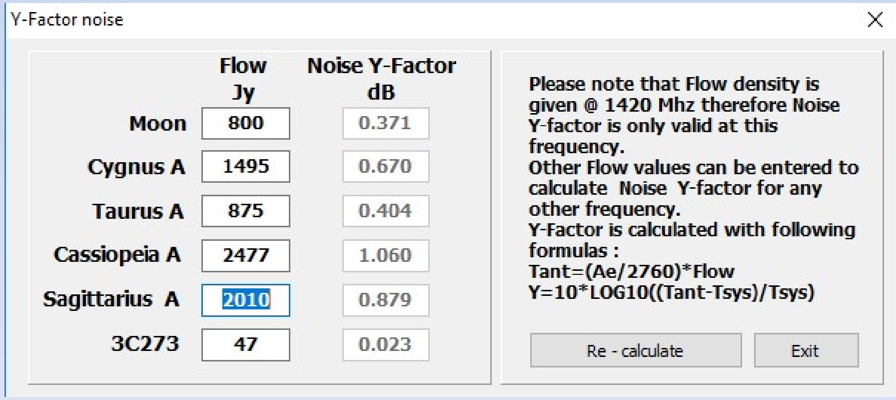
Murmur



Mhz	Learmonth 0500 UTC	San Vito 1200 UTC	Sag Hill 1700 UTC	Penticton 1700 UTC	Penticton 2000 UTC	Palehua 2300 UTC	Penticton 2300 UTC	Best set
245	-1	13	-1	-1	-1	-1	-1	13
410	-1	28	-1	-1	-1	-1	-1	28
610	-1	-1	-1	-1	-1	-1	-1	-1
1415	49	47	-1	-1	-1	-1	-1	47
2695	72	77	-1	-1	-1	-1	-1	77
2800	-1	-1	-1	-1	-1	-1	-1	-1
4995	117	117	-1	-1	-1	-1	-1	117
8800	227	218	-1	-1	-1	-1	-1	218
15400	539	508	-1	-1	-1	-1	-1	508

#	Date	Hour	Frequency (Mhz)	Antenna Gain (dBi)	Tsys (K)	SFU (KJy)	Expected Noise (dB)	Measured Noise (dB)	Delta (dB)	Comments
1	28/06/2018	19:22:11	1296	35.016	43.980	469809	17.27	16.5	0.776	Dummy #1
2	28/06/2018	19:22:19	1296	35.016	43.980	469809	17.27	16.8	0.476	Dummy #2
3	28/06/2018	19:22:25	1296	35.016	43.980	469809	17.27	16.3	0.976	Dummy #2

By clicking the button «Show Y-factor for all noise sources» it is also possible to calculate the noise of a few other cosmic radio sources.



	Flow Jy	Noise Y-Factor dB
Moon	800	0.371
Cygnus A	1495	0.670
Taurus A	875	0.404
Cassiopeia A	2477	1.060
Sagittarius A	2010	0.879
3C273	47	0.023

Presently this feature works at 1400Mhz, but it is possible to directly enter Flux data in Jy to obtain Noise factors at other frequencies.

Hunting for Pulsars

Murmur 6.0.0 …. One more little thing …

The program version (6.0.0) released this week has a very useful new feature : *PLAN Observation* that shows the hourly positions (Az/El) of all radio sources and all PSR of the internal data base filtering results with a specific Radio Horizon.

Murmur 6.0.0 12-Aug-2018 mario.natali@gmail.com

Location	Latitude
Assisi-Beviglie	43.0922

SAVE current set as default | SET Observati

(●) Dish antenna ( ) Other antenna

Dish diameter	5	m
Dish efficiency	50	%
Sensitivity constant Ks	1	
Frequency	1303	Mhz
Line loss before LNA	0.1	dB
LNA Noise figure	0.23	dB
LNA gain	38	dB
Line loss after LNA	0.5	dB
Receiver noise figure	4	dB
T sky	4	K
T spillover	10	K
T atmosphere	0	K
Integration time	18000	sec.
Integration bandwidth	56000	KHz

PLAN Observation

Tracking table ordered by S1400 calculated for 8/13/2018 local time

Object	S/N	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Moon												094:15	105:26	117:35	132:44	152:50	175:53	199:52	220:47	236:38	249:29				
Sun											097:29	109:40	124:50	145:57	173:61	202:60	227:54	244:45	257:34	268:24					
Cygnus-A		233:86	267:76	276:65	284:54																067:39	074:50	081:60	089:71	104:82
Taurus-A							090:33	101:44	115:55	136:63	169:69	206:67	234:60	251:50	264:40										
Cassiopeia		045:57	040:65			337:72																			045:50
Sagittarius-A		213:10																			148:10	160:15	174:18	188:18	201:15
3C273													097:10	108:21	120:31	135:40	154:46	176:49	198:48	218:42	235:34	248:25			
B0833-45	684																								
B1641-45	211																								
B0329+54	203					053:56	051:65	041:73		332:76															031:19
J0437-4715	91																								
B0950+08	41										099:21	110:31	124:41	142:49	165:54	191:54	214:50	233:43	247:33	259:23					
B0736-40	28												176:06	187:06											
B1451-68	35																								
B1933+16	25	201:62	226:56	244:47	258:36	269:25															095:30	107:40	122:50	143:59	171:63
B1556-44	25																								
B2020+28	19	174:76	221:72	247:63	262:53																	085:40	096:51	110:62	133:71
B1929+10	19	200:57	223:51	240:42	254:32	265:21														090:16	100:27	113:37	128:47	148:54	174:58

Radio Horizon

Azimuth	0	30	30	60	60	90	90	120	120	150	150	180	180	210	210	240	240	270	270	300	300	330	330	360
Minimum. Elevation	80		50		30		5		5		5		5		5		20		50		90		90	

Re-calculate | Save Horizon | - 1 day | + 1 day | Exit

Expected S/N is calculated based on parameters entered in the first screen . Hourly data indicate Azimuth and Elevation and are based on above radio horizon

MDS 10.36 mJy

The analysis does not take into account the polarization of the signal as this parameter is strongly depending on the specific Pulsar. Please evaluate carefully case by case as this may deteriorate performance up to 3dB.

Max. integration bandwidth KHz
(without de-dispersion)

Show all PSR List

PLAN Observation

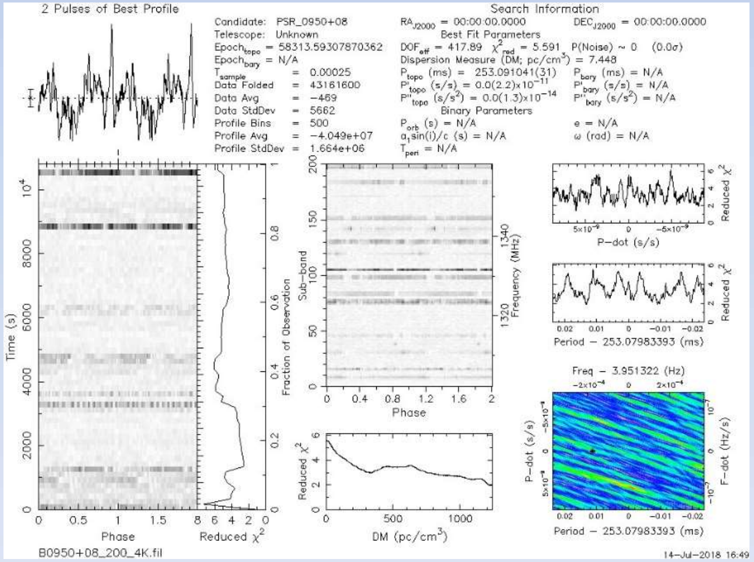
Calculated S/N		
Azimuth		deg
Elevation		deg

Evaluation done only for following frequency intervals :
390Mhz-500Mhz and 1,000Mhz - 1,500Mhz

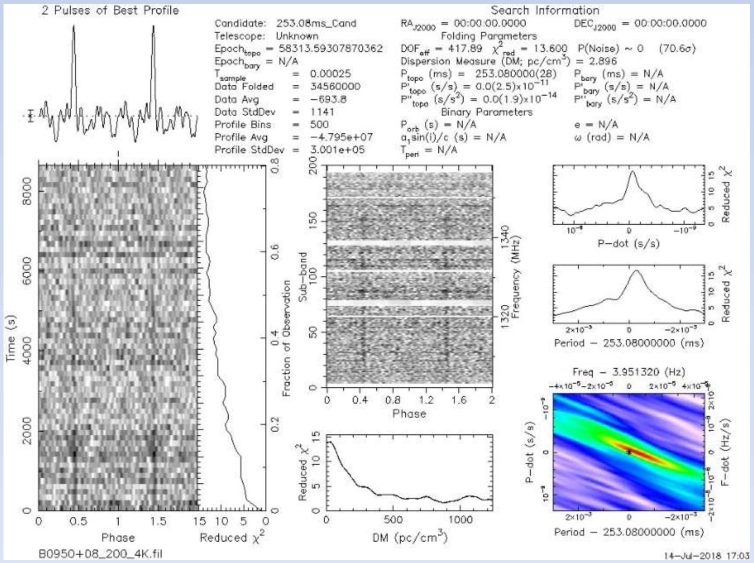
Hunting for Pulsars

Results @ I0NAA

PULSAR DETECTED		B0329+54	B0329+54	B1642-03	B1933+16	B1929+10	B2020+28	B0950+08
Center frequency	Mhz	1297	409	1303				1330
Integration Bandwidth	Mhz	2	2	10				56
Intergration time	s	7200	9120	18000				10800
Antenna Gain	dB	33	23	33				33
Antenna feeder	type	W2IMU	BFR	W2IMU				W2IMU
Preamplifier NF	dB	0.23	0.45	0.23				0.23
Preamplifier Gain	dB	38	60	38				38
T Sky	K	4	10	4				4
T Spillover	K	10	10	10				10
System MDS	mJy	86.98	123.2	24.52				13.37
System noise temperature	K	36.98	59.15	36.98				36.98
Software for recording		IW5BHY (Windows)	IW5BHY (Windows)	IW5BHY (Linux)				I1NDP(Linux)
Software for analysis		PRESTO (Linux)	PRESTO (Linux)	PRESTO (Linux)				PRESTO (Linux)
Receiver type		RTL-SDR	RTL-SDR	AirSpy				ETTUS B200mini
GPSDO		NO	NO	YES				YES
Date of detection		26 Jan 2017	30 Jan 2017	17-nov-17	18-nov-17	27-nov-17	28-nov-17	14 July 2018



B0950+08 recording before RFI mitigation



B0950+08 recording after RFI mitigation

Capture of PSR B0950+08 showing the powerfull RFI mitigation function of PRESTO.

Without RFI mitigation is impossible to see PSR pulses.

Hunting for Pulsars

Future plans

- ✓ **MURMUR, like everyhthing else in the ham shack, is always changing and hopefully, improving !**
- ✓ **Planned new features and improvements :**
  - ✓ **Improve Y-factor noise calculations.**
  - ✓ **Automatic loading of flow data for cosmic sources.**
  - ✓ ~~**Add possibility to define visible horizon and observation plan.**~~
  - ✓ **Add the capability to make sun noise measurements directly from MURMUR whilst incorporating a fine tuning algorithm for automatic antenna pointing.**
  - ✓ **Allow automatic update of Pulsar data base from the ATNF catalogue.**

Any suggestions, corrections and requests for additional features are welcome !

I1NDP Nando

Nando.pellegrini@tiscali.it

A brief introduction

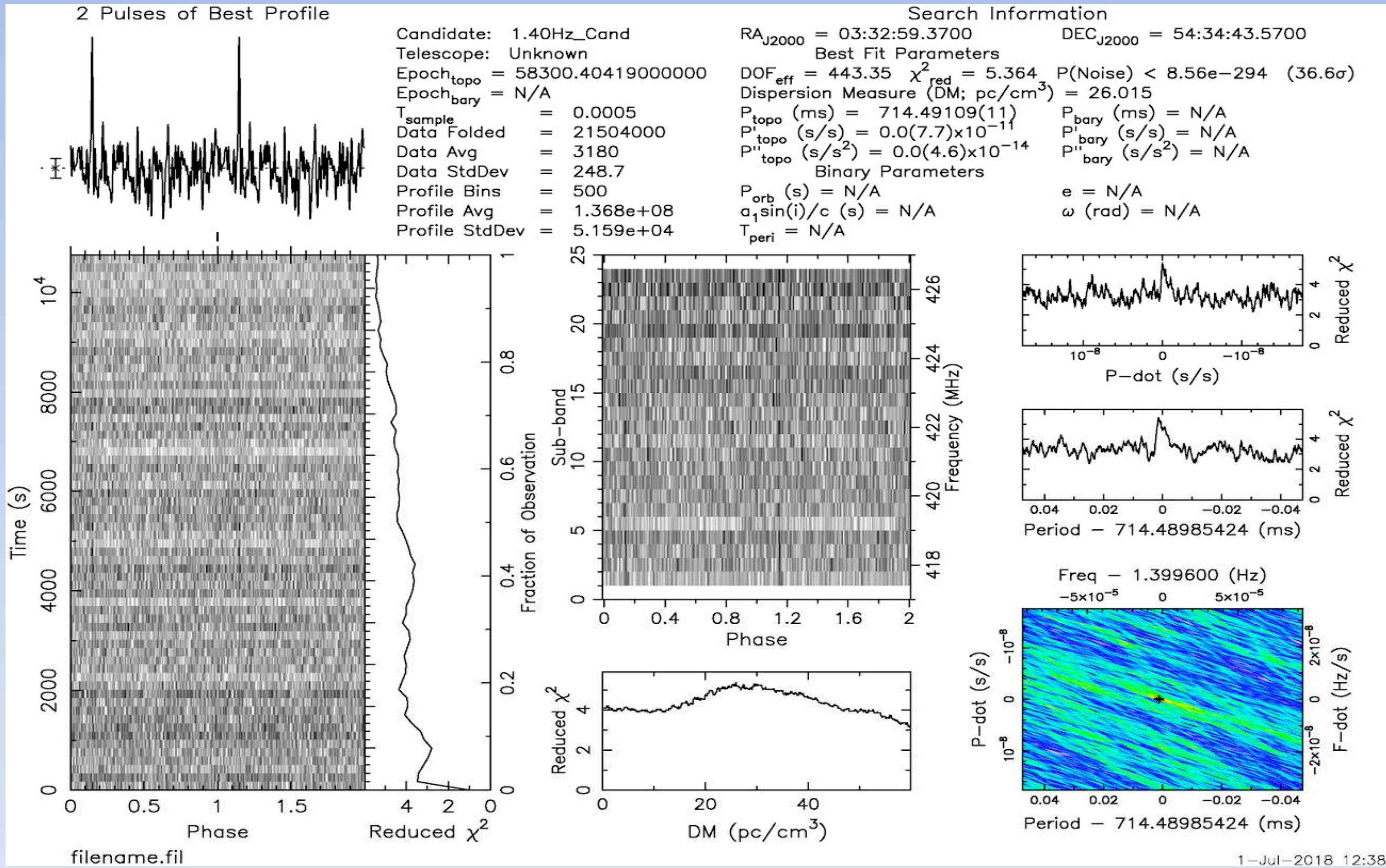
The subject may appear as not compatible with the spirit of our conference, I try to explain why might be otherwise:

- ✓ Big challenge for weak signals hunters
- ✓ Achievable results with a medium/small sized 70cms EME system or a good 23cm system
- ✓ A Fascinating and absorbing subject with a lot to learn
- ✓ Moon is not always available

IW5BHY, Andrea and is 70cm Antenna
A good example of a big result

B0254+54 Detection

with an home made TV type antenna
without rotator and tracking



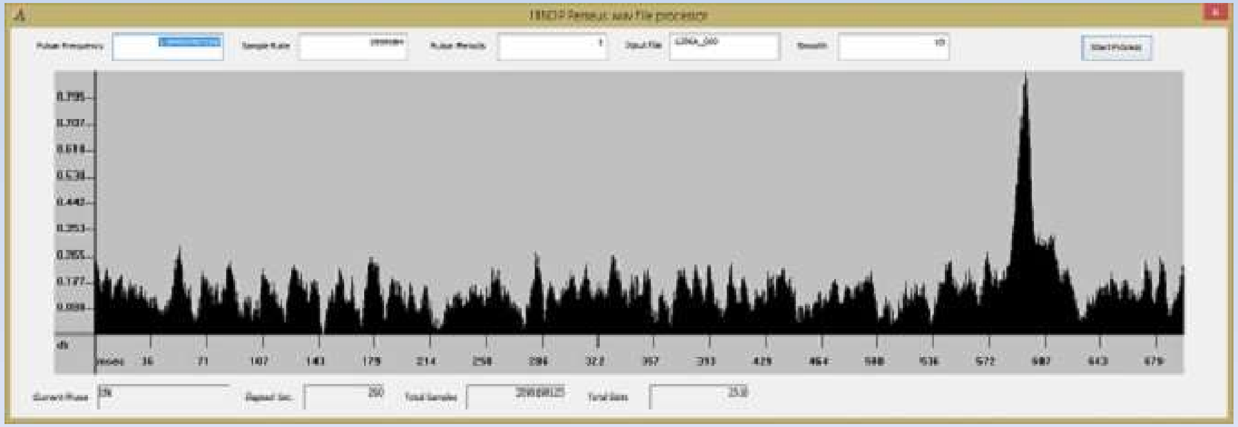
Short History

- First pulsar Observation made in 2014
- Very little knowledge
- 70 cms unusable due to RFI so forced to use 23cm
- Only 2Mhz RX bandwidth
- No external frequency reference was available
- Home made post processing software

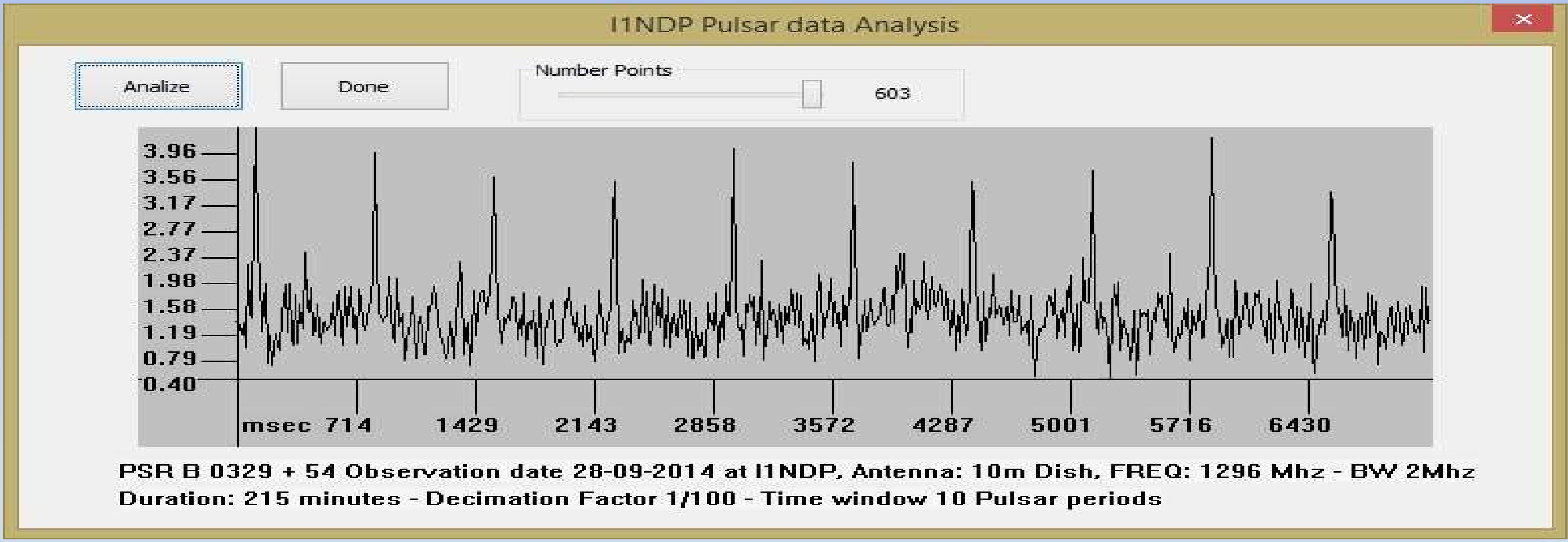
2014 Results

- Very first pulse
- Certified by K1JT

To my knowledge first pulsar detection on 23 cm with an amateur observatory



2014 Results



Next setup

- Years 2016-2017 used the IW5BHY system
- 23 pulsar detected – used 23cm exclusively
- Realised maximum capability of my amateur observatory

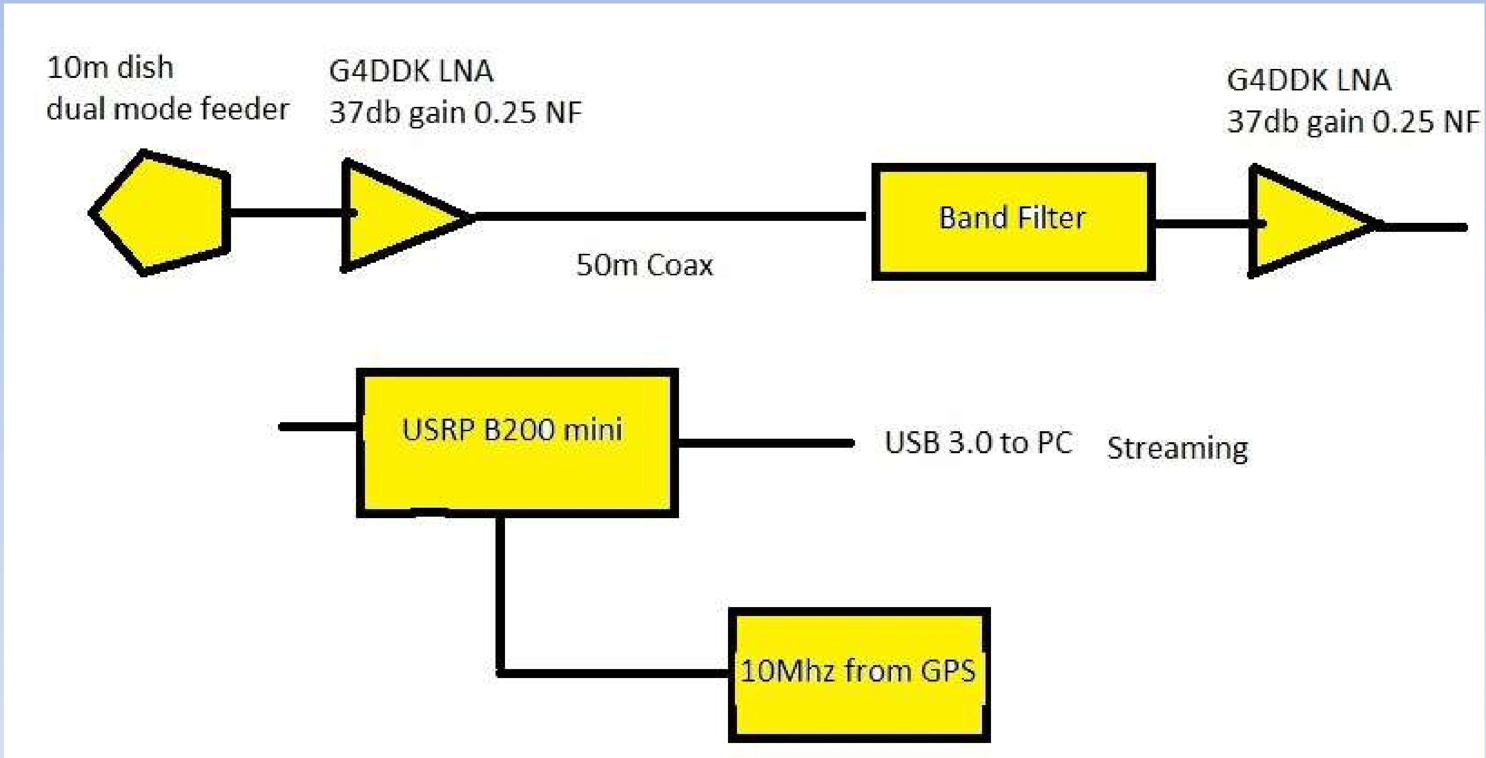
Year 2018 new Radiotelescope

- First attempt with RedPitaya board,unsuccessful
- Very promising with more than 100Mhz bandwidth
- Failed due to insufficient documentation for programming the FPGA using internal interfaces
- Not possible to transfer high data rate otherwise

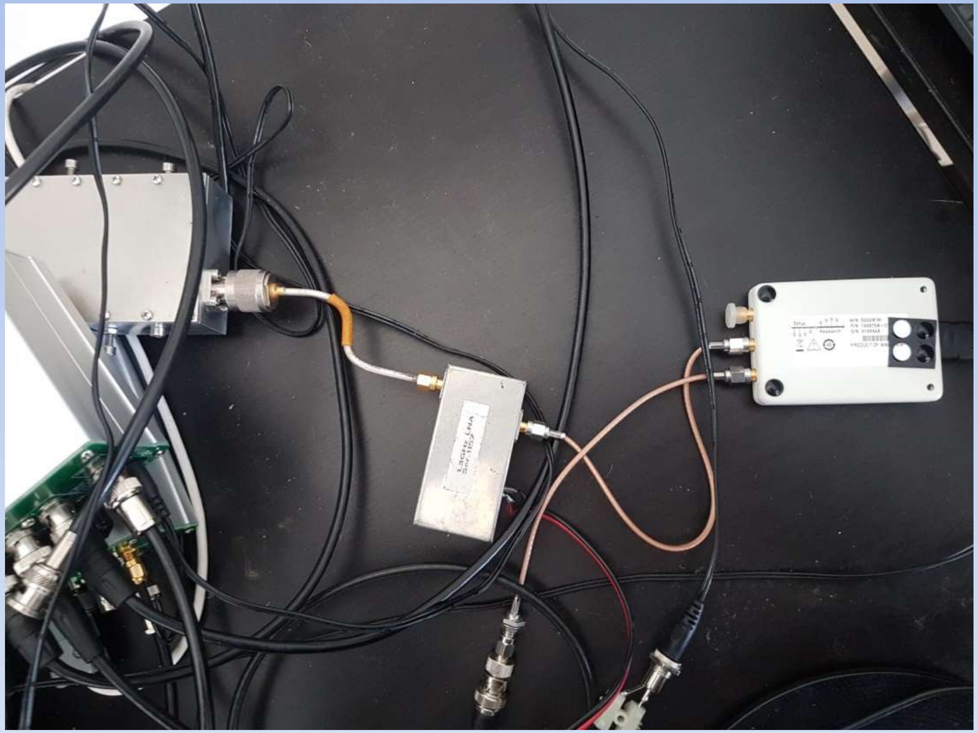
New Attempt

- Ettus research USRP B200mini
- SDR with maximum 56Mhz sample rate
- USB 3.0 with high transfer rate(up to 5Gb)
- 12 bit fast ADC
- Doubts about being able to process the high transfer rate on a Linux PC

Receiver Chain



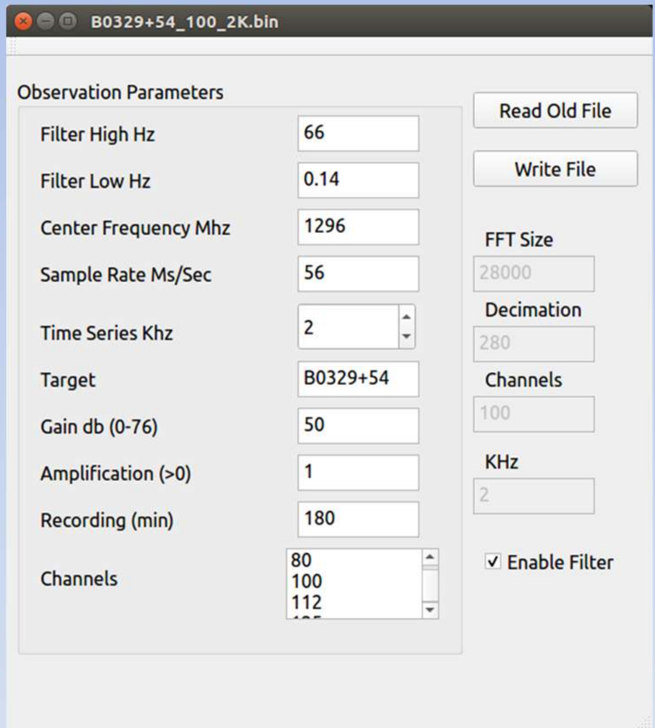
Raw Picture on the bench



Software

- Difficult handle 56Mhz x by 8 bytes I/Q float samples (448 MB/sec) without loosing a single sample
- I7 processor with multithreading, highest priority and no other activity
- Software in 3 blocks

Configurator



- Dumb graphic interface for entering the observation parameters

Data Acquisition

- The most critical process, spread on 5 threads
- The receiving thread at real time priority
- Receive streaming from USB
- Transform from time to frequency domain (FFT)
- Decimate and integrate the samples
- Write a .bin file to SSD

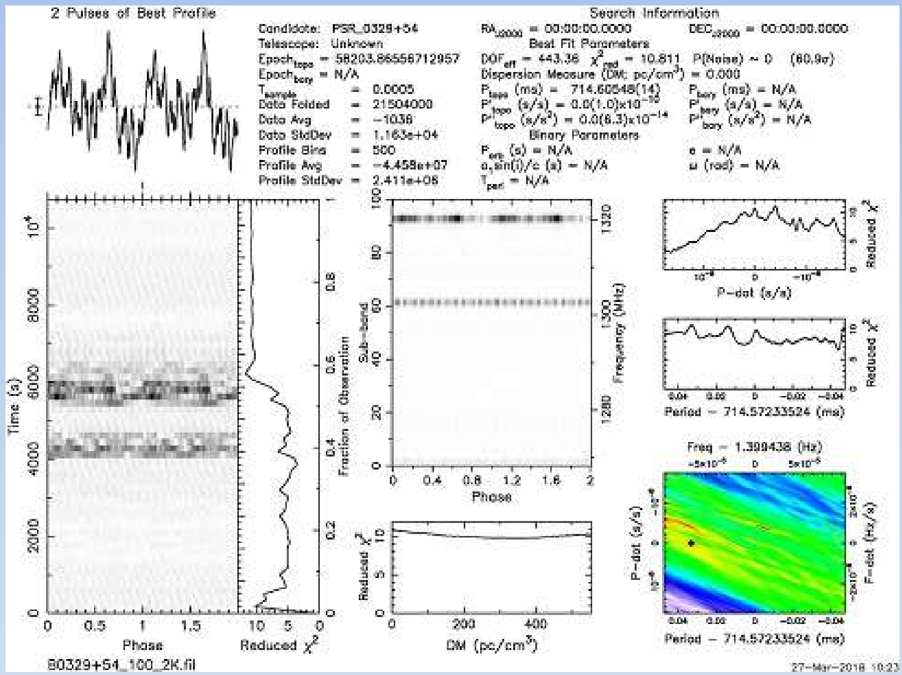
BinToFil

- Simple converter to make the .bin compatible with the presto suite
- Add on provide an optional band pass filter tailored to the target pulsar
- It could be integrated with data acquisition, kept as separate step to give more flexibility

2018 Results (1)

- Only first impressions available at the moment
- The 23cms seems to have more spurs than before – seems ‘dirtier’
- Wider bandwidth and greater number of channels facilitates better RFI mitigation

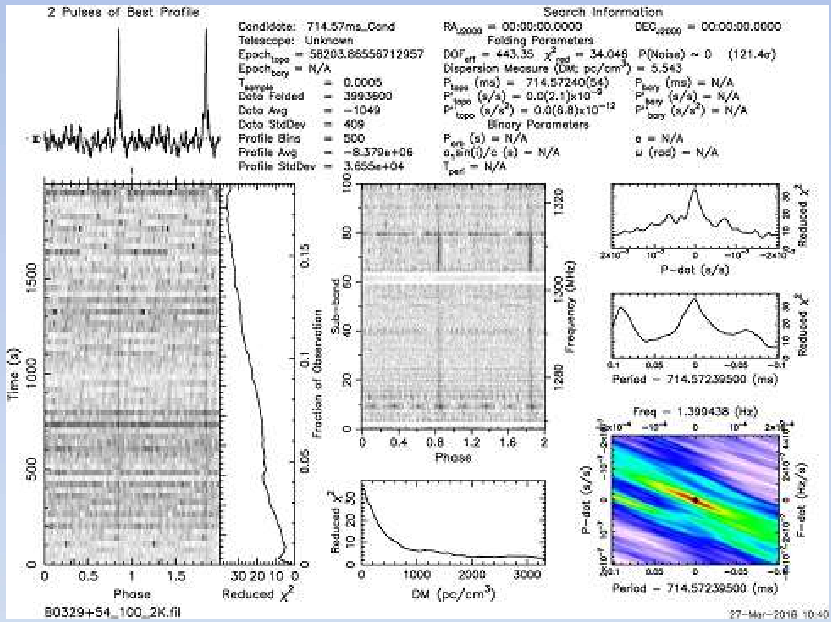
2018 Results (2)



3 hours of recording at 56Mhz with 100 channels of the strongest Pulsar visible in the Northern Hemisphere.
Not Very gratifying

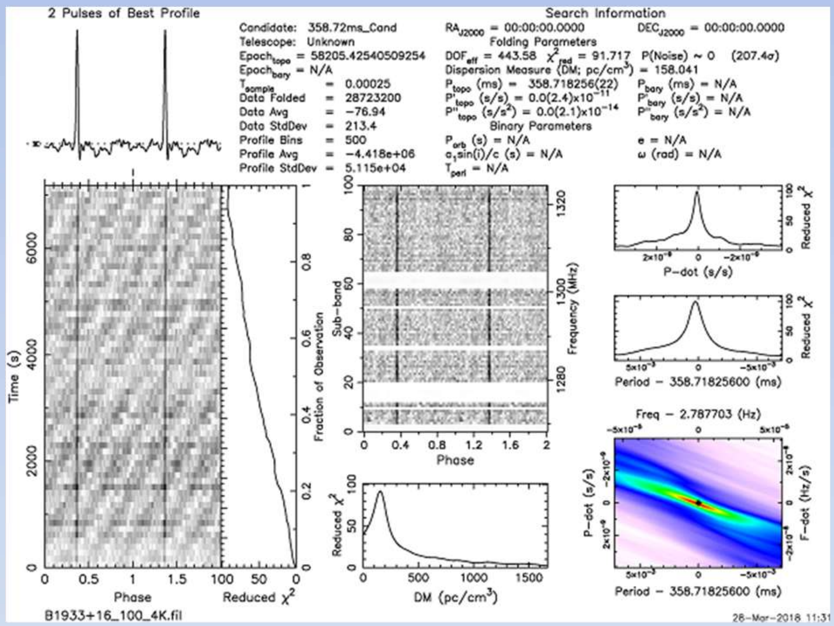
- First approach
- No sign of the pulsar

2018 Results (3)



- Same recording as before
- After deep cosmetic surgery
- Only the 18.5 % of the data saved

2018 Result (4)

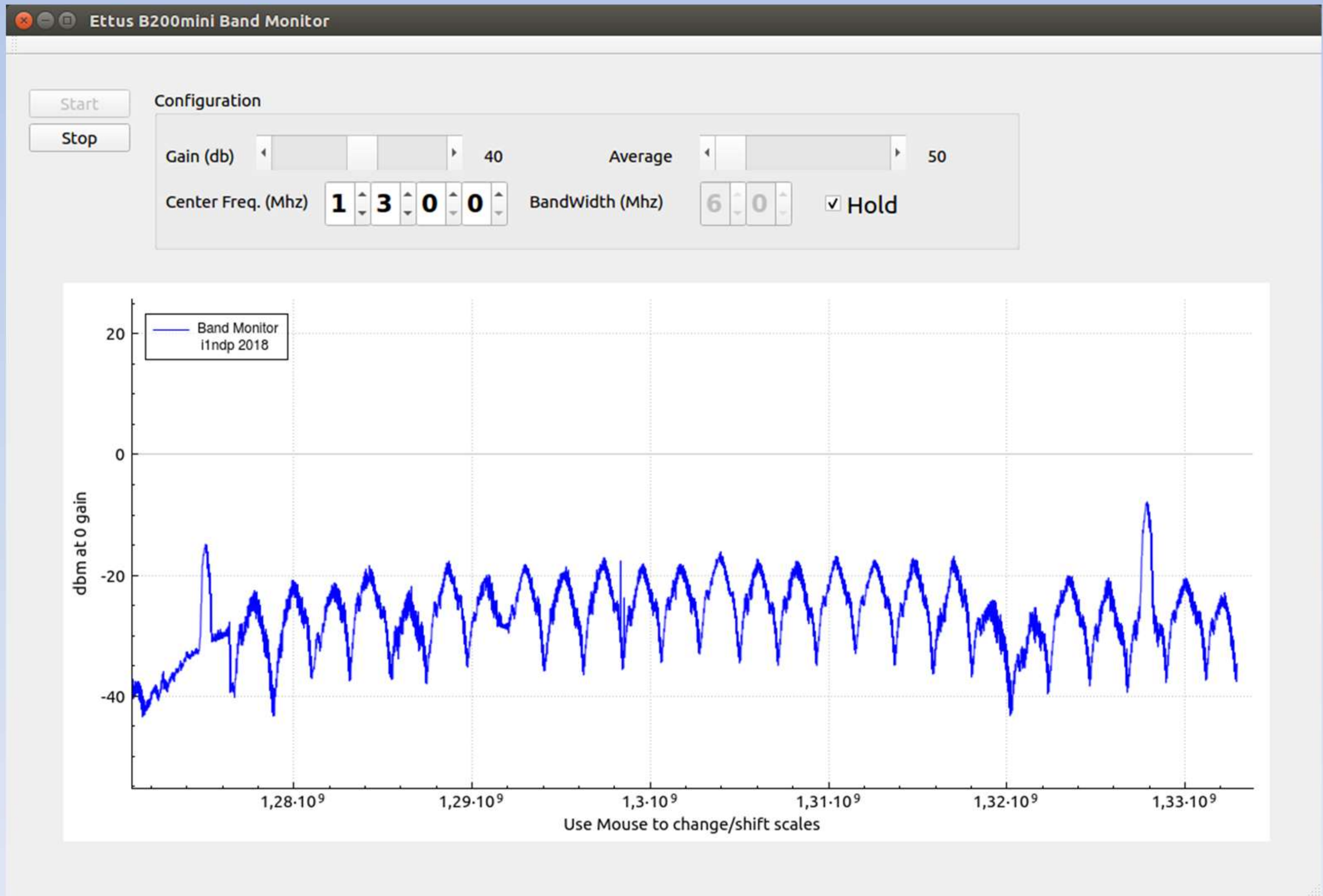


- Fortunately we can do better , with some luck

Latest News

- The 23cm band RFI is worse than ever
- Further Pulsar searches at my site do not seem possible
- Source of pollution seems to due to the heavy presence of radar
- Signals are between 1 and 3 MHz wide with a very short pulse duration (μsec)
- The image shows a 60MHz wide window centered at 1300MHz, acquired in a short time
- Band occupation is from 1215 to 1400 MHz

- Screen shot taken using the peak hold facility of a B200mini utility designed to be used as a band monitor
- The signals are of very short duration and go unnoticed during normal EME activity



Conclusion

- RF Environment is not the same everywhere
- Interested to know if anyone has knowledge of 23cm occupancy
- Willing to help anyone who is interested in searching for pulsar

OE5JFL Hannes

oe5jfl@aon.at

Results OE5JFL (7.3m Offset Dish)

Software:

IW5BHY
Murmur (I0NAA)
Presto

54 pulsars detected

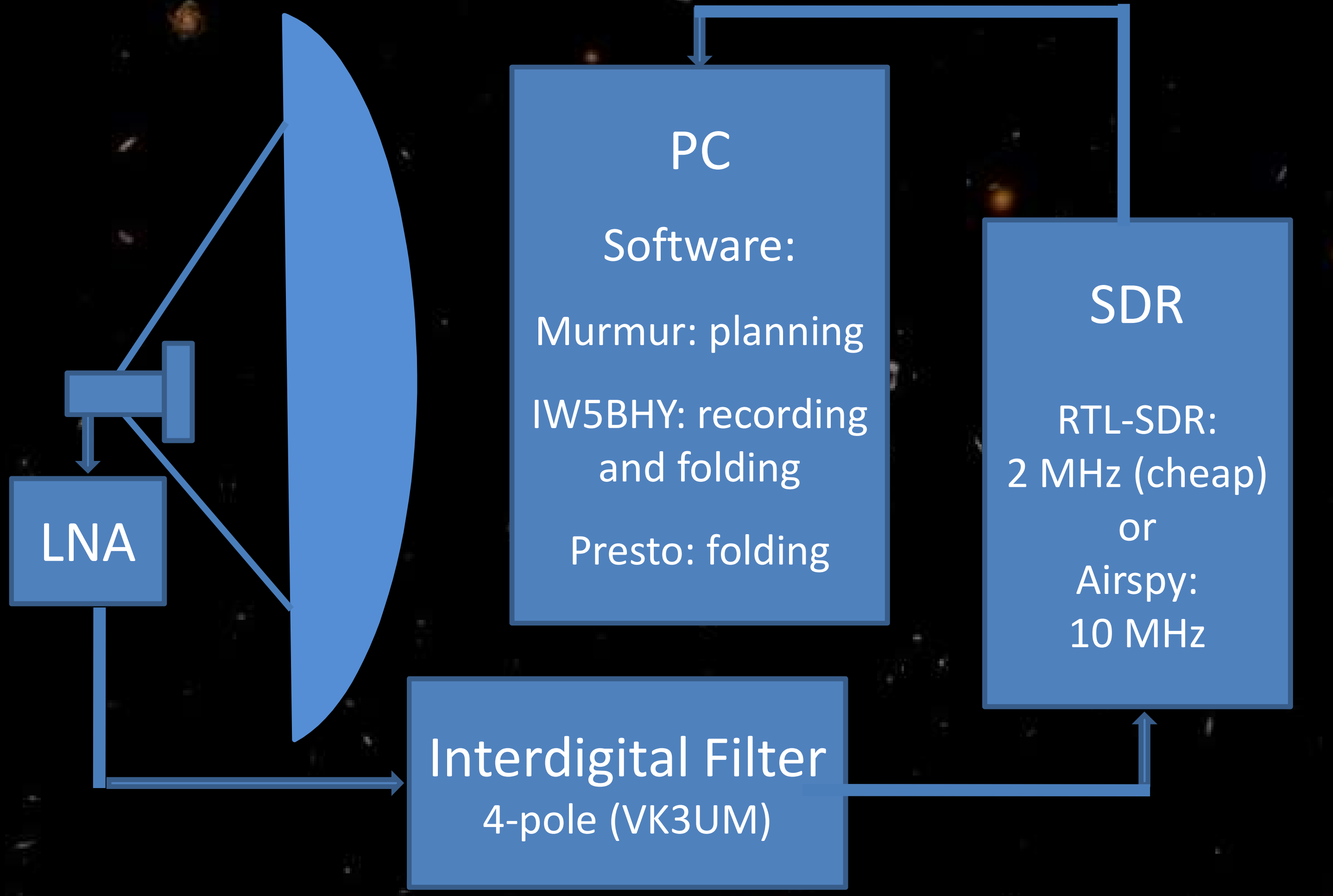
47 on 70cm,
18 on 23cm,
11 both bands

Weakest:

70cm B0626+24: 31mJy

23cm B1845+01: 8.6mJy

Setup Block Diagram



Comparing Signal Strength

1 Jansky(Jy) = 10^{-26} W/(m^2*Hz)

Sun: 500 000 Jy (23cm)

Moon: 500 Jy (23cm)

B0329+54 (strongest pulsar):

Mean flux: 1.5 Jy (70cm), 0.25 Jy (23cm)

Peak flux: 150 Jy (70cm), 25 Jy (23cm)

→ Peak of pulse 13dB below moon noise on 23cm

5m dish: 0.25dB moon noise on 23cm

experience:

20dB more necessary for „good pulse“ in SSB bandwidth (S/N 8 dB)

13+20= 33dB too low on 23cm ! (for real time)
8dB more on 70cm → 25dB too low (90m dish o.k.)

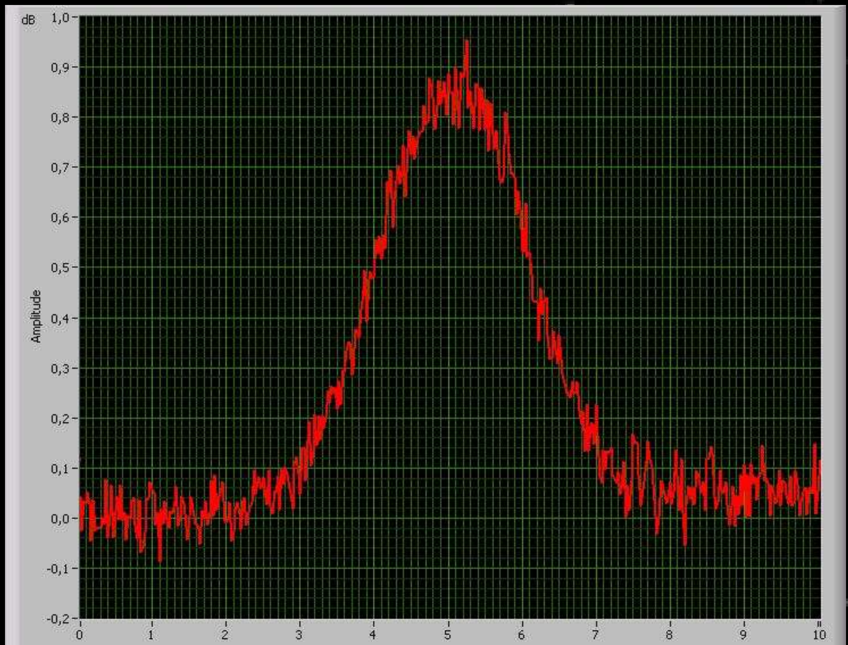
solution: reducing noise amplitude by using more bandwidth and folding

2.5kHz→ 2MHz: 19dB better
100 seconds observation time (folding): 10dB better

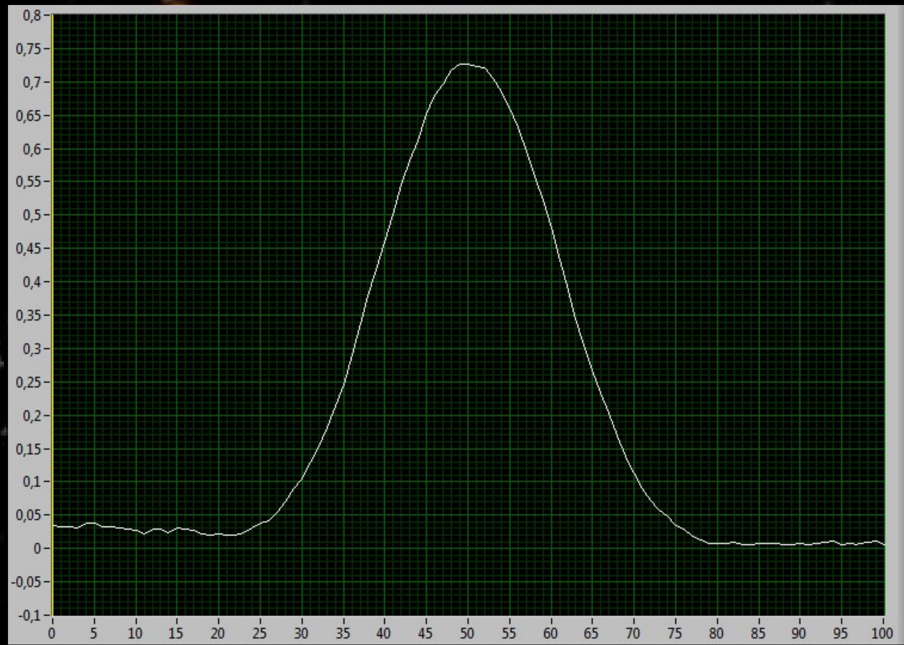
5m dish 23cm: 1 hour observation time
3m dish 70cm: 40 minutes observation time

Measurement of low level broadband noise: influence of bandwidth

23cm moon noise



2,4 kHz bandwidth

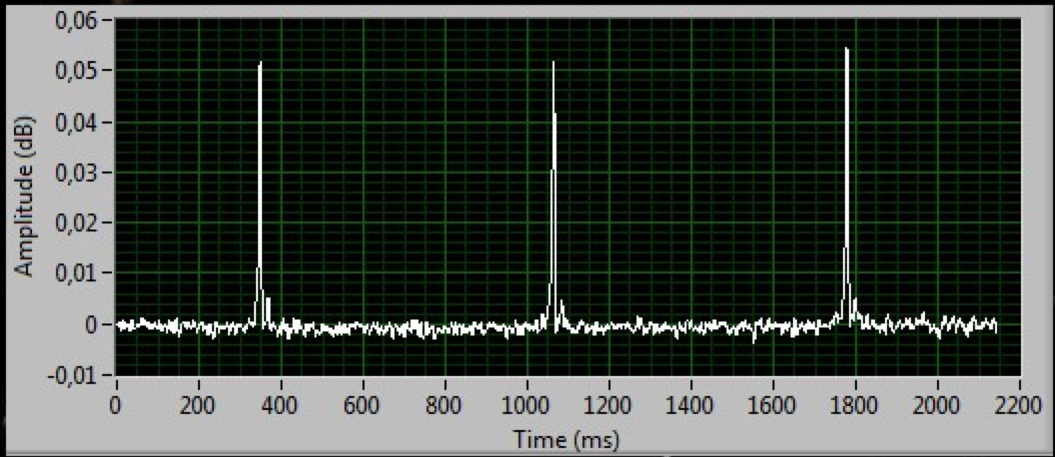


2 MHz bandwidth

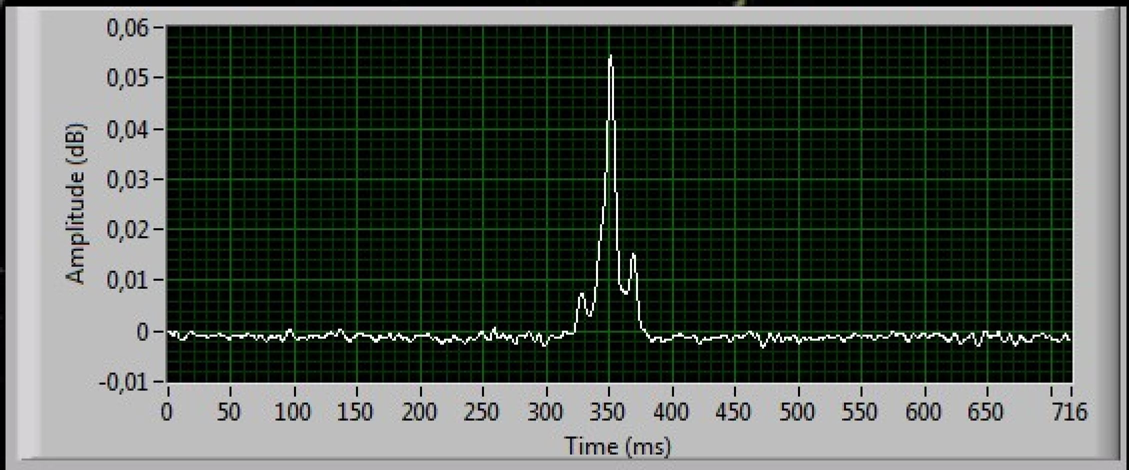
Pulsar B0329+54

Frequency 1,39 Hz → 714 ms period

folding software: IW5BHY



3 pulses 424 MHz

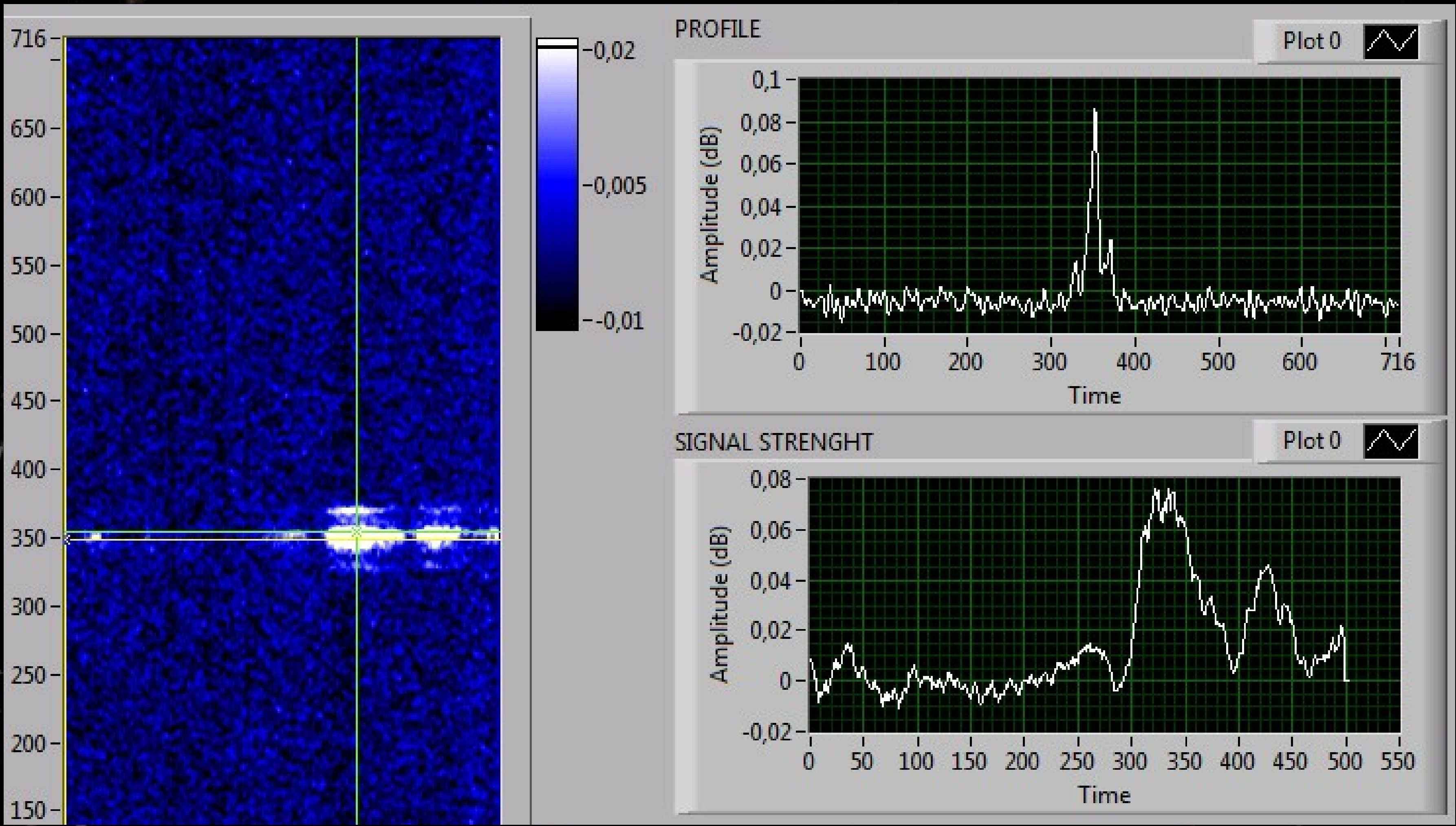


pre- and postpulse in normal mode 1294 MHz

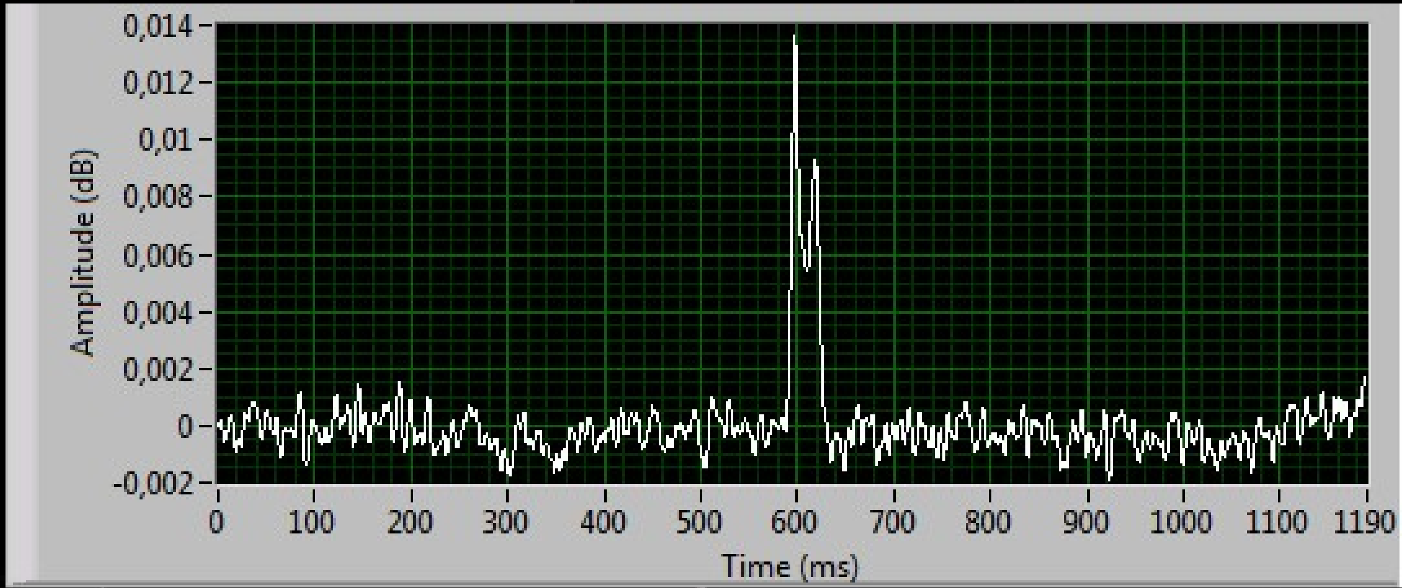
QSB by scintillation on 23cm

waterfall software: IW5BHY

observation time: 5 hours

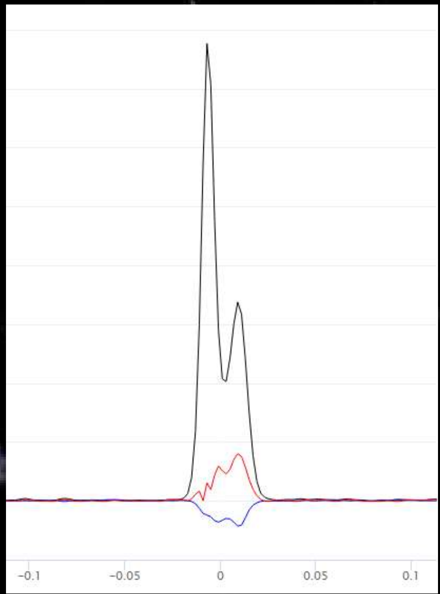


Pulsar B1133+16 double pulse (424 MHz)



measured pulse

profile confirmed by
EPN profile catalogue



Crab-pulsar B0531+21

Young pulsar, exists since a supernova explosion in 1054
(observed on earth as a star even visible at daylight for about two years)

Rotates 30 times per second

Fast speed slowdown: 1% in 25 years, 1ppm in less than one day!

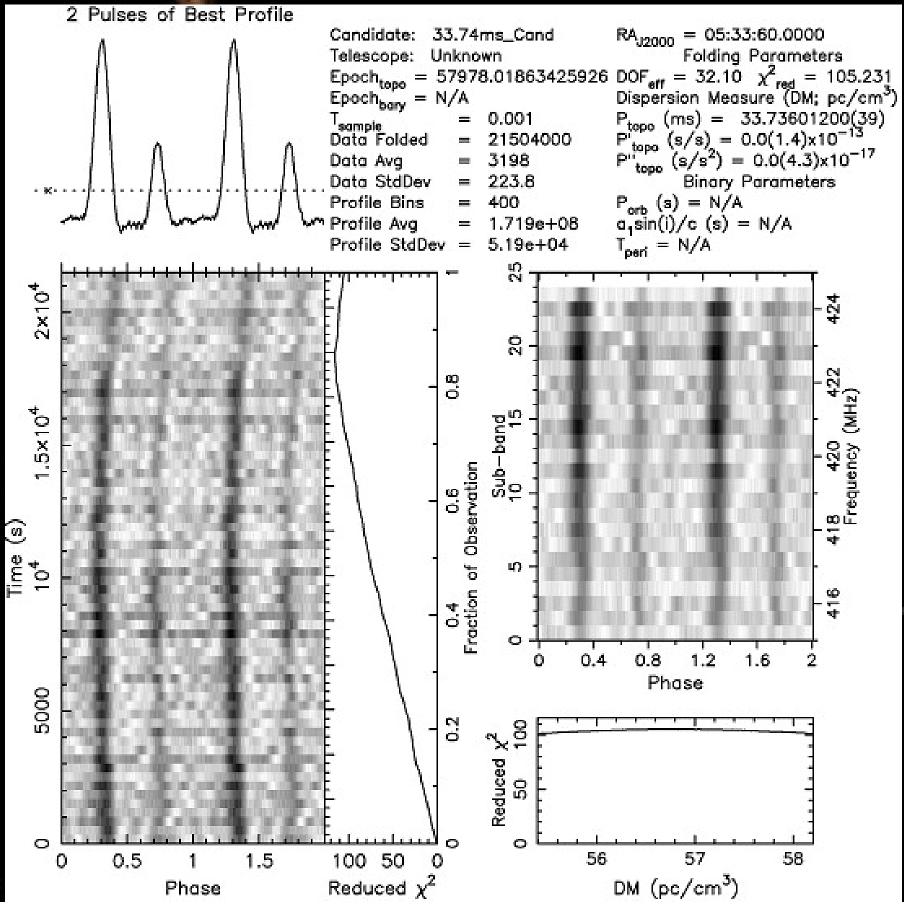
Highly dispersed : 6,4 ms per MHz is more than the pulse width,
at 10 MHz bandwidth dispersion is 2 periods!

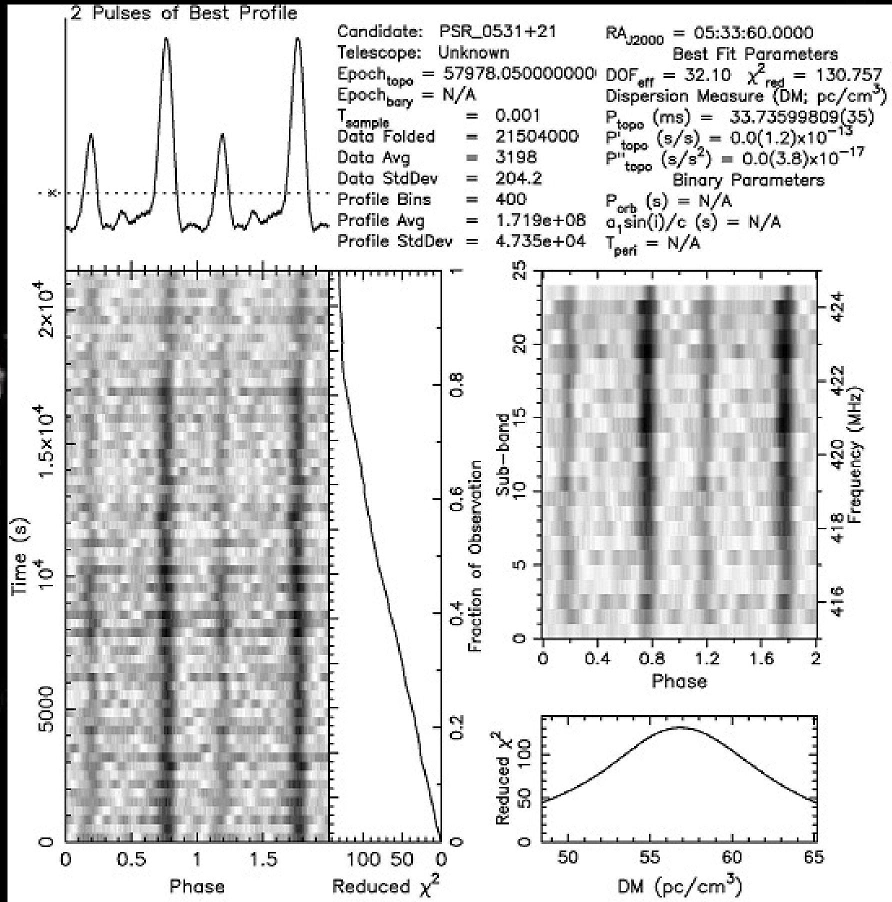
produces “giant pulses”

In an observation file of B0525+21 the Crab signal was found as well with good S/N, including giant pulses

Crab pulsar 6 hours observation

software: Presto



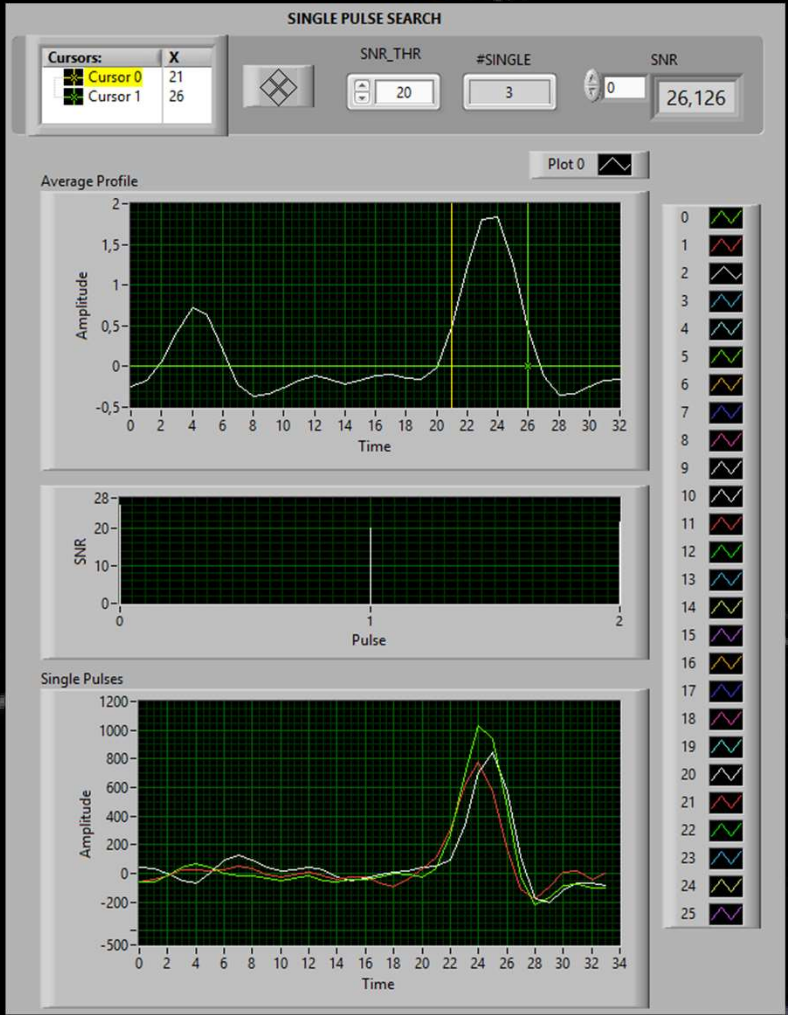


folding without frequency tracking

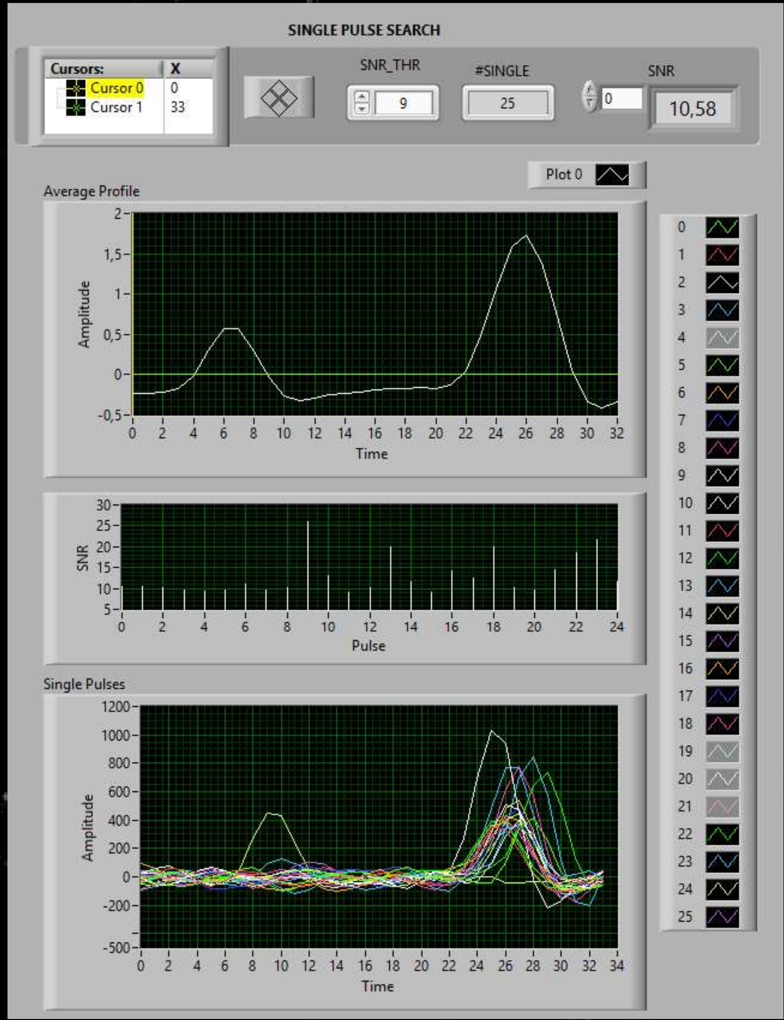
folding with frequency tracking

Crab Pulsar: Giant Pulses

software: IW5BHY



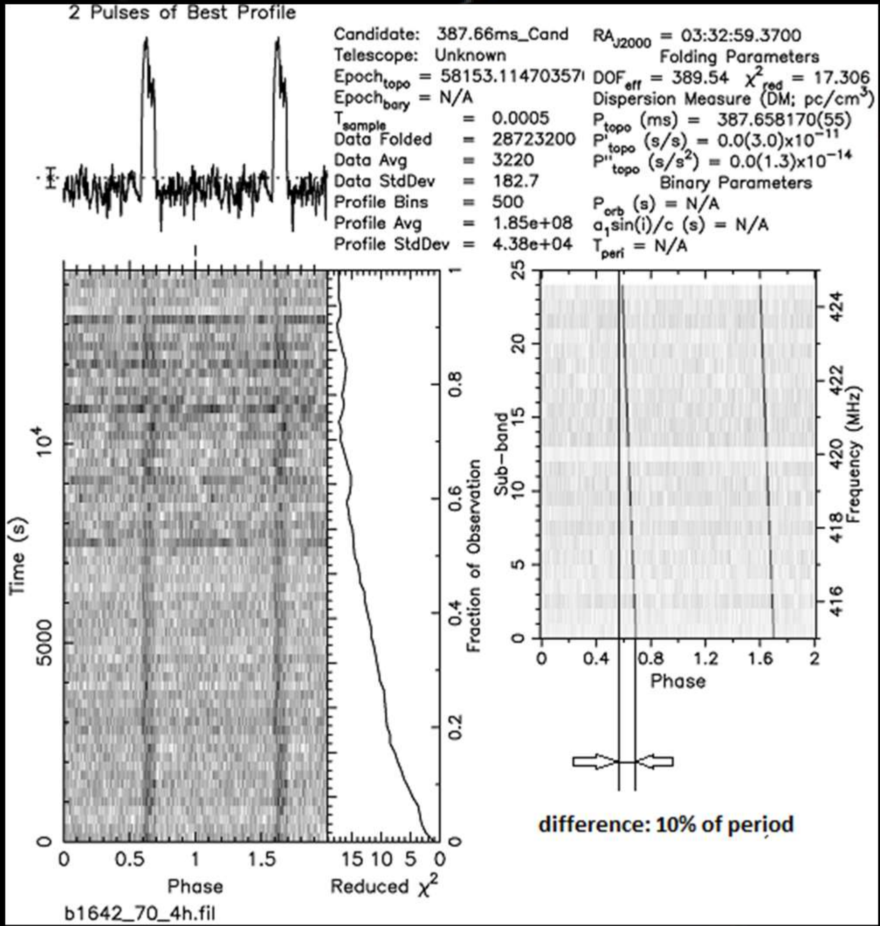
3 best giant pulses (high limit)



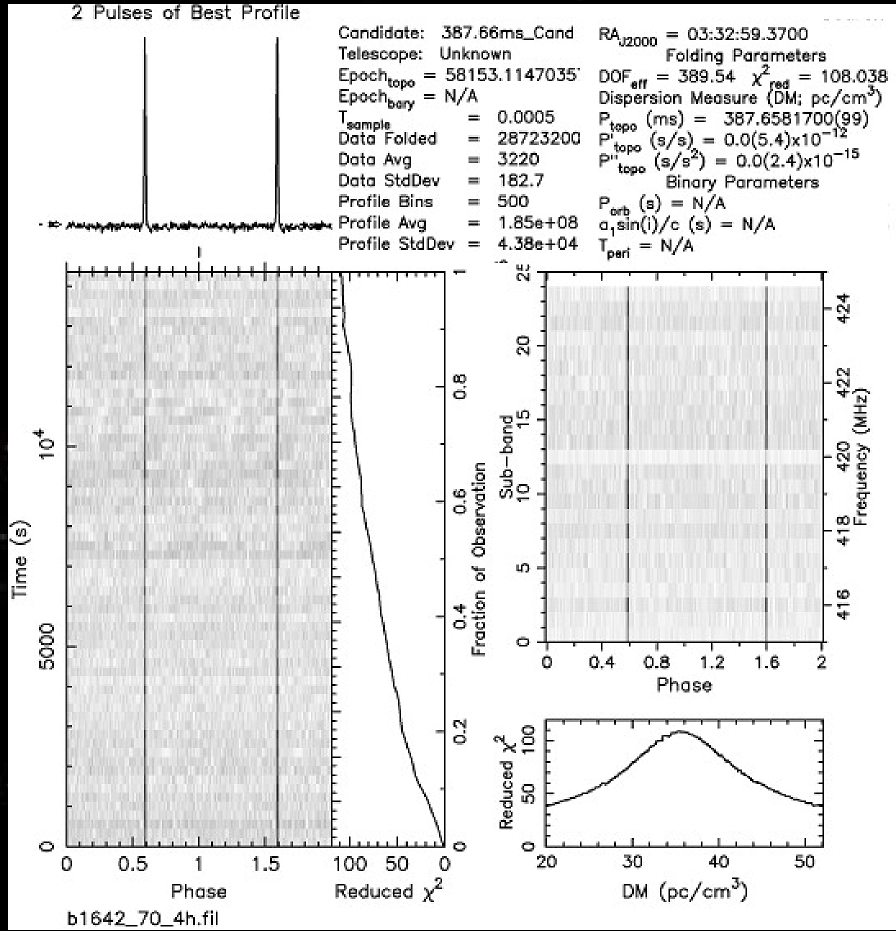
21 best giant pulses, one interpulse

B1642-03: period 388ms, pulse width 4ms

dispersion DM=35,76 → 4ms/MHz (40ms/10MHz)



folding without de-dipersion:
pulse smeared, low S/N



folding with de-dispersion:
pulse very sharp, high S/N

Results With 3m Dish:

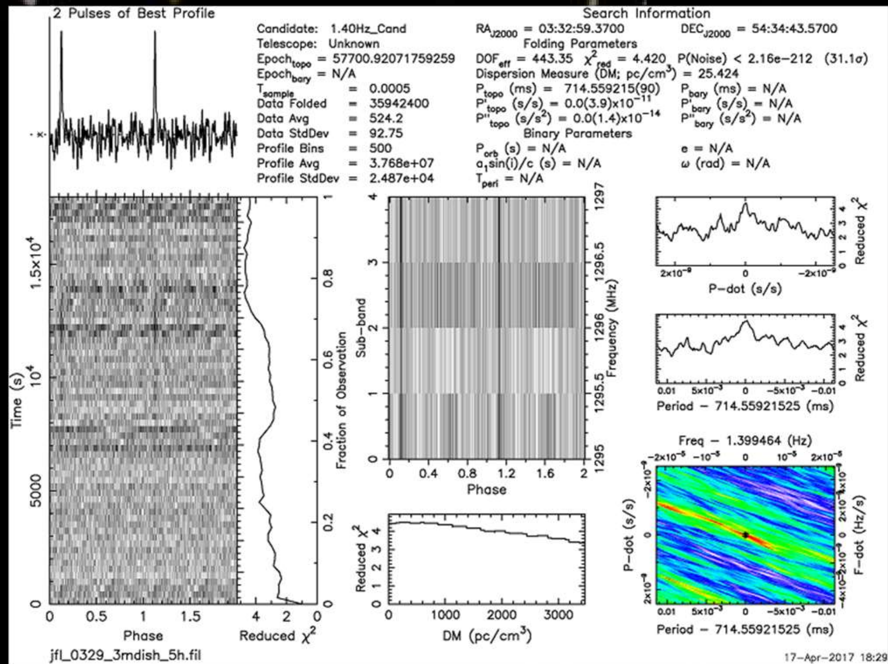
1 pulsar on 23cm: B0329+54

4 pulsars on 70cm: B0329+54, B0950+08, B1642-03, B1929+10

23 cm B0329+54:

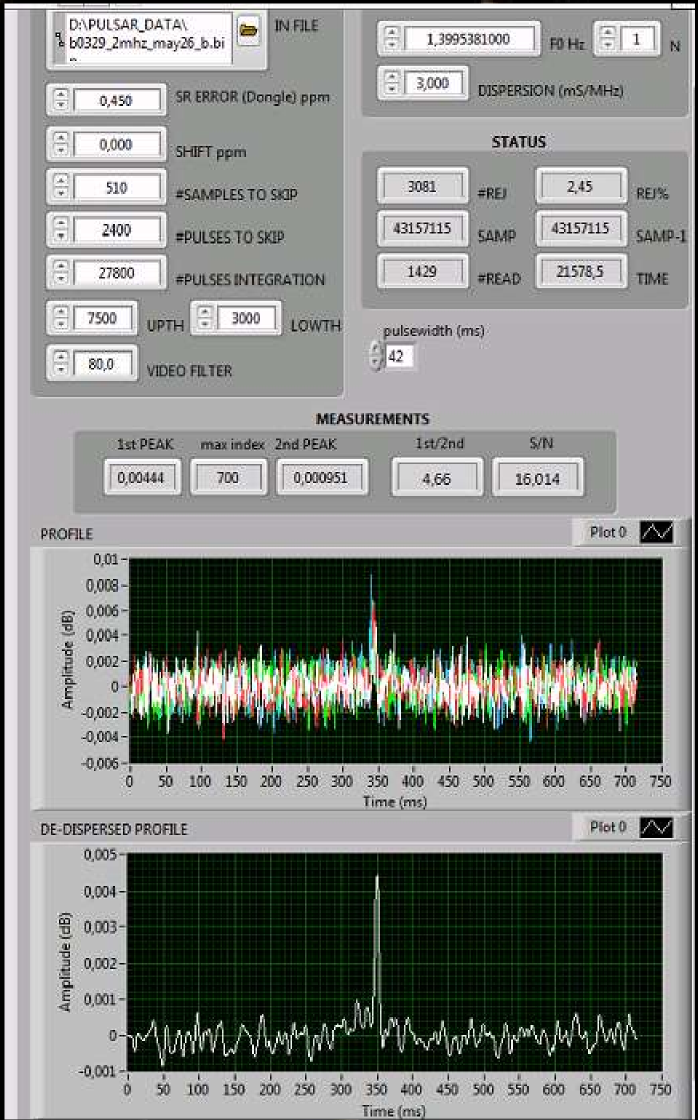
RTL-SDR, 2 MHz bandwidth

10 observations, 5 hours each,
only 1 positive result !



70 cm Observation B0329+54 With 3m Dish

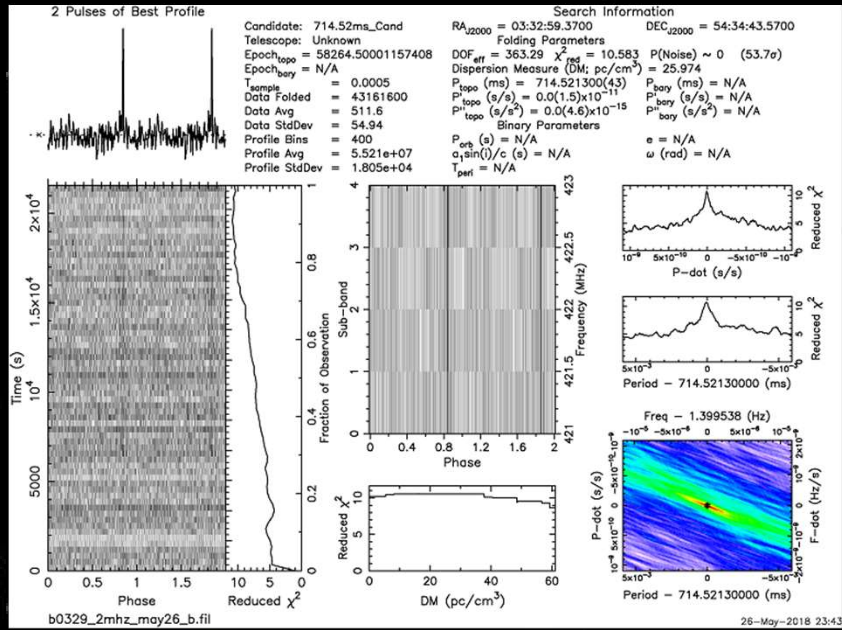
6 hours, parallel 2 MHz and 10 MHz

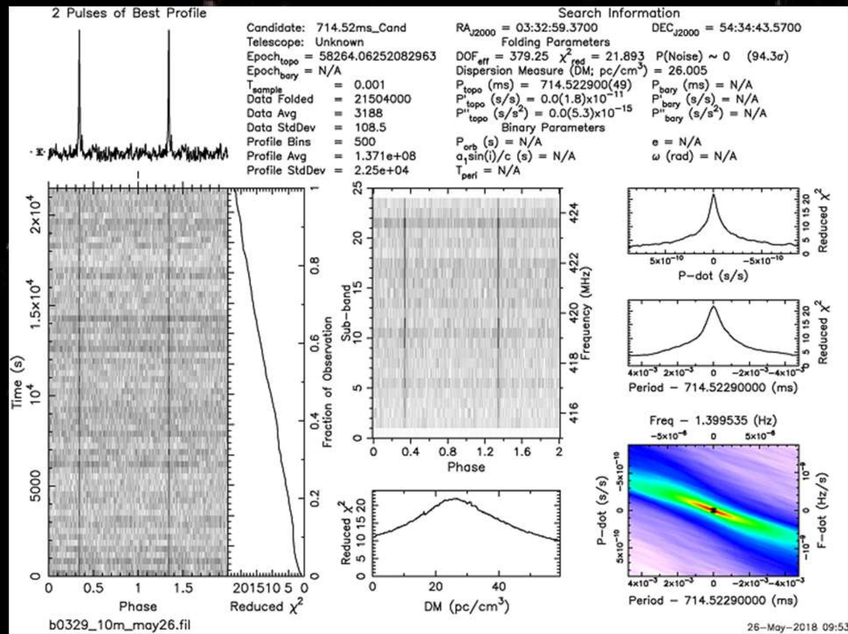


2 MHz Presto →

2 MHz IW5BHY ←

10 MHz Presto →





thank you for your attention

I0NAA	Mario
I1NDP	Nando
OE5JFL	Hannes