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Results of O1 narrow-band searches with the 5-vectors method

DCC: G1601736

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Outline:

- Physical motivation
- Reminder of 5-Vectors narrow-band pipeline
- Target pulsars and searched parameters
- Candidates selection
- Upper-limit
- What’s next and conclusion

Physical motivation

Narrow-band searches are performed to take into account a possible frequency mismatch between the GW emission and Electromagnetic observations.

- Uncertainties in parameters observations: The longer is the analyzed data chunk the better we must know frequency and spin-down.
- Physical reason: Is it possible to have a “little” mismatch in the rotational frequency of the rotational layers of the pulsars.

It is the important to explore a narrow region around the expected GW parameters

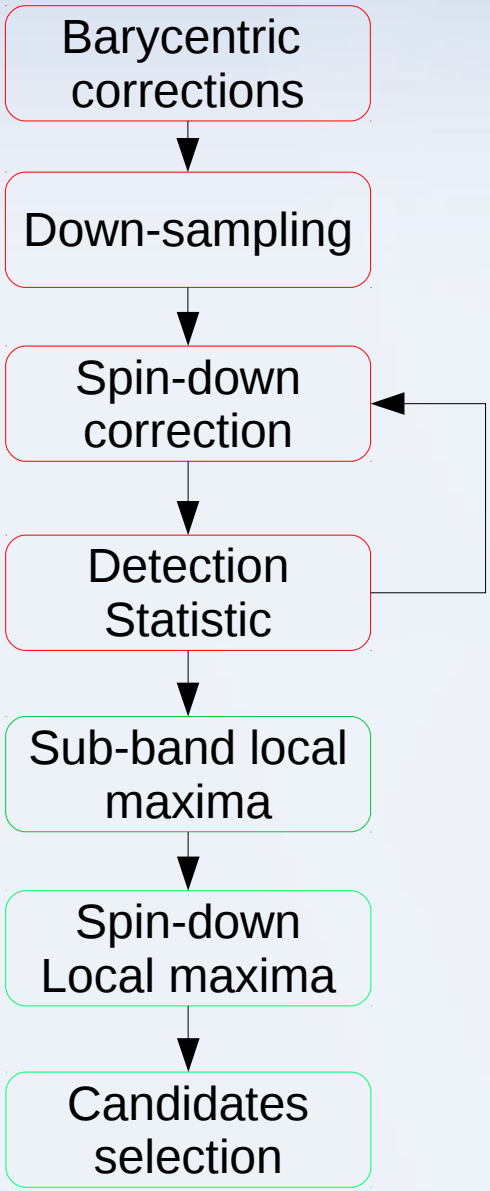
Reminder of 5-Vectors narrow-band pipeline

The pipeline uses the 5-vectors to search for a CW signal over a frequency/spin-down grid centered around the expected values
(PhysRevD.89.062008 for details on the method)

Some improvements has been done:
1./ Implementation of FFT grid → Faster computation
2./ Interbinning→ Reduce sensitivity loss
3./ New upper-limit procedure → Faster computation
currently under review, referees: Andrzej and Karl.
(https://wiki.ligo.org/CW/RomeNarrowband wiki page of the review)

The new algorithm allow us to explore ~1Hz band and ~200 different spin-down corrections for a fully coherent search using 4 months of data in a few detector hours.

Reminder of 5-Vectors narrow-band pipeline



Applied on time:

$$\tau_1 = t + \Delta_R + \Delta_E - \Delta_S$$

Applied on the phase of the signal:

$$y'(\tau) = y * e^{-i\phi_{sd}(t)}$$

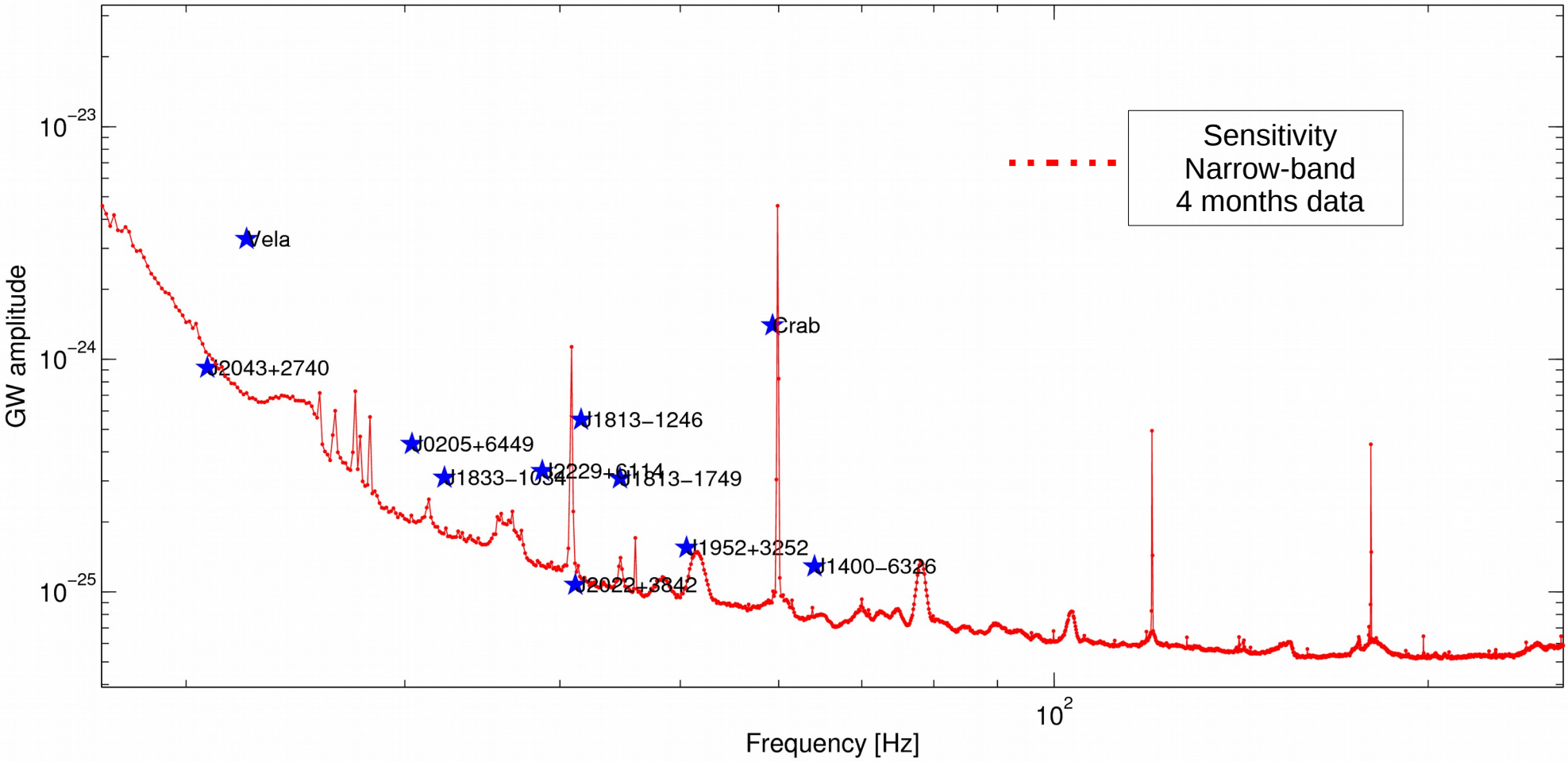
Detection statistic relation:

$$S = |\vec{A}^{+}|^4 |\vec{H}_{+}|^2 + |\vec{A}^{x}|^4 |\vec{H}_{x}|^2$$

We extrapolate the tails of the experimental noise-only distribution corresponding to a p-value= 1% (taking into account the number of trials)

Target pulsars and searched parameters

We have selected 9 pulsars “interesting” pulsars, including J2043+2740 and J2022+3842 for which the spin-down limit can be barely beaten.



Target pulsars and searched parameters

We have performed a joint search over the full LHO and LLO datasets **(C01 calibration)**

The corresponding frequency and spin-down bins are respectively:

$$\delta f = 9.43 \cdot 10^{-8}\mathtt{Hz} \qquad \delta \dot{f} = 8.90 \cdot 10^{-15}\mathtt{Hz/s}$$

The observation time is short enough that is not necessary to consider more than one second order spin-down bin.

Target pulsars and searched parameters

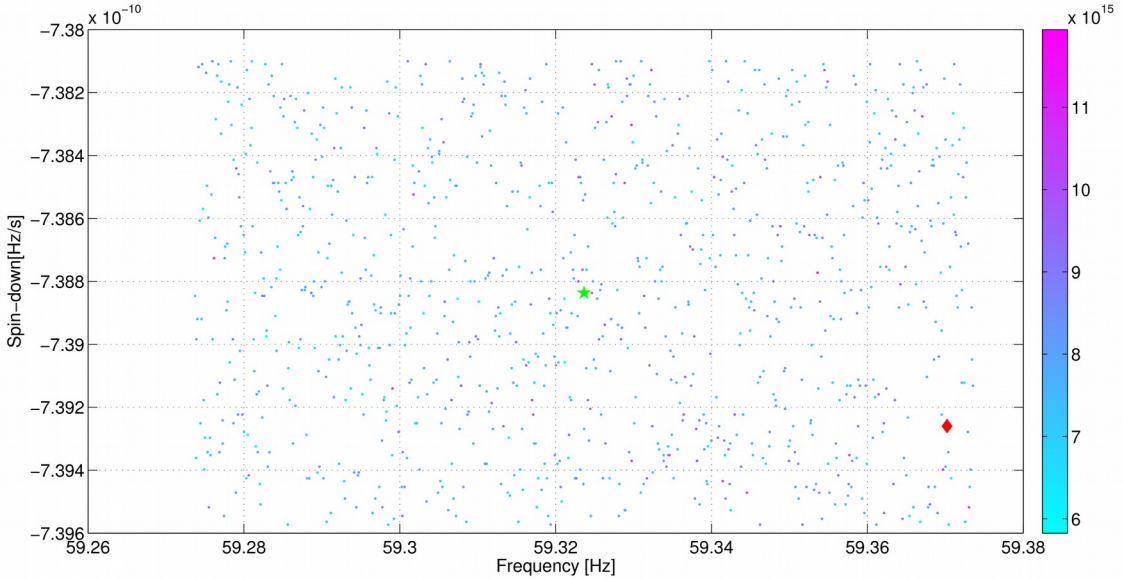
	Central Freq [Hz]	Freq. Band [Hz]	Central spin-down [Hz/s]	Spin-down band [Hz/s]	#Freq.bins	#SD bins
Crab	*59.32365204*	*0.1*	*-7.3883e-10*	*1.48e-12*	*18.5 x 10^6*	*161*
J0205+6449	*30.40958196*	*0.03*	*-8.9586e-11*	*1.75e-13*	*2.5 x 10^6*	19
J1813-1246	*41.60103328*	*0.04*	*-1.2866e-11*	*6.43e-14*	*3.4 x 10^6*	*7*
J1813-1749	*44.71284639*	*0.03*	*-1.5000e-10*	*3.03e-13*	*2.5 x 10^6*	*33*
J1833-1034	*32.29409580*	*0.04*	*-1.0543e-10*	*2.11e-13*	*3.4 x 10^6*	*23*
J1952+3252	*50.58823360*	*0.05*	*-7.4797e-12*	*6.43e-14*	*4.3 x 10^6*	*7*
J2043+2740	*20.80486277*	*0.05*	*-2.7415e-13*	*6.43e-14*	*4.3 x 10^6*	*7*
J2229+6114	*38.71531561*	*0.06*	*-5.8681e-11*	*1.19e-13*	*5.1 x 10^6*	13
Vela	*22.37409813*	*0.03*	*-3.1191e-11*	*6.43e-14*	*2.5x 10^6*	*7*
J1400-6326	64.12537215	*0.07*	-8.0017e-11	*1.75e-13*	*6.5 x 10^6*	*19*
J2022+3842	41.16008453	*0.04*	-7.2969e-11	*1.60e-13*	*3.4 x 10^6*	*17*

Candidates selection

We have selected the local maxima of the detection statistic over 10^{-4} Hz Sub-bands (over the different spin-down corrections)

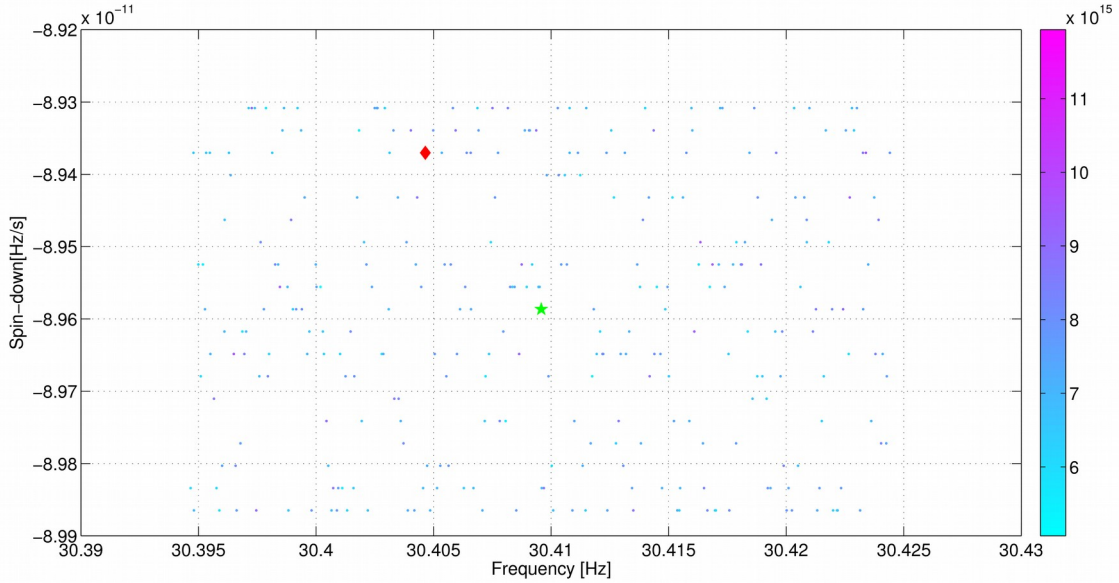
Among the maxima we have selected candidates corresponding to a p-value of 1% or less.

Candidates selection



Crab:

	Freq[Hz]	SD [Hz/s]	P
C01	59.37021006	-7.3926e-10	0.005

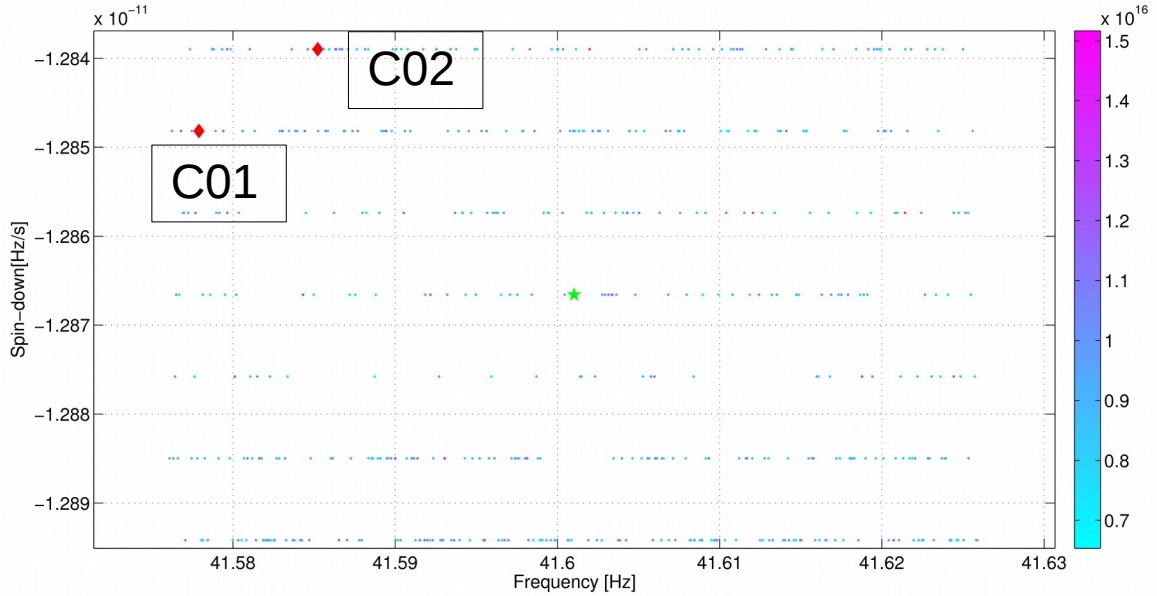


J0205+6449:

Glitch @ MJD 57344

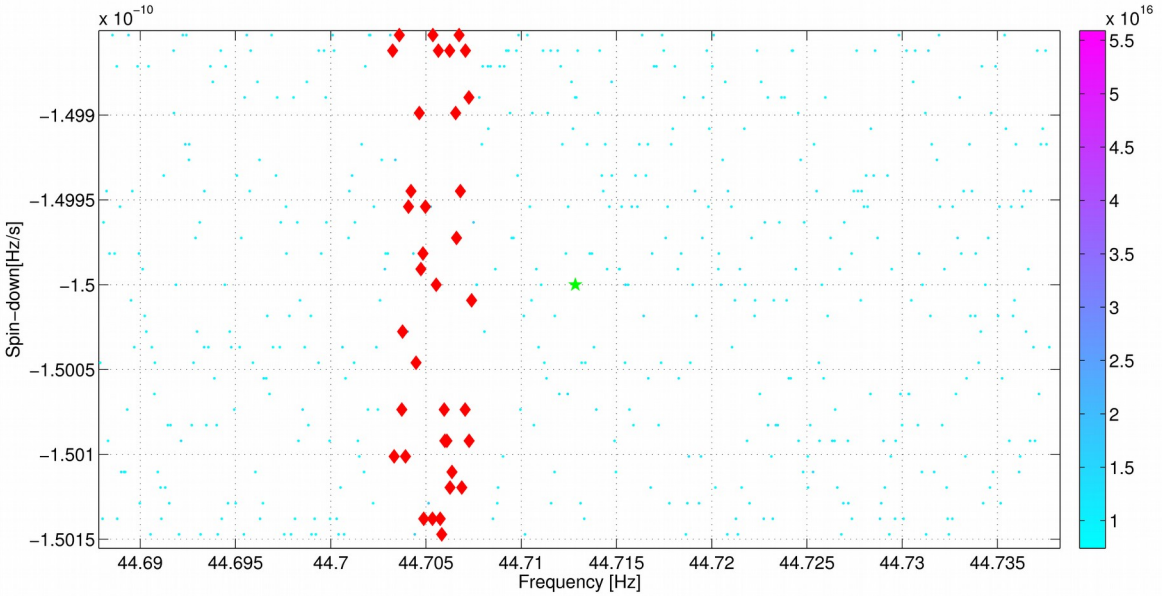
	Freq[Hz]	SD [Hz/s]	P
C01	30.40464802	-8.9370e-11	0.003

Candidates selection



J1813-1246:

	Freq[Hz]	SD [Hz/s]	P
C01	41.57791015	-1.2848e-11	0.007
C02	41.58522643	-1.2838e-11	0.005

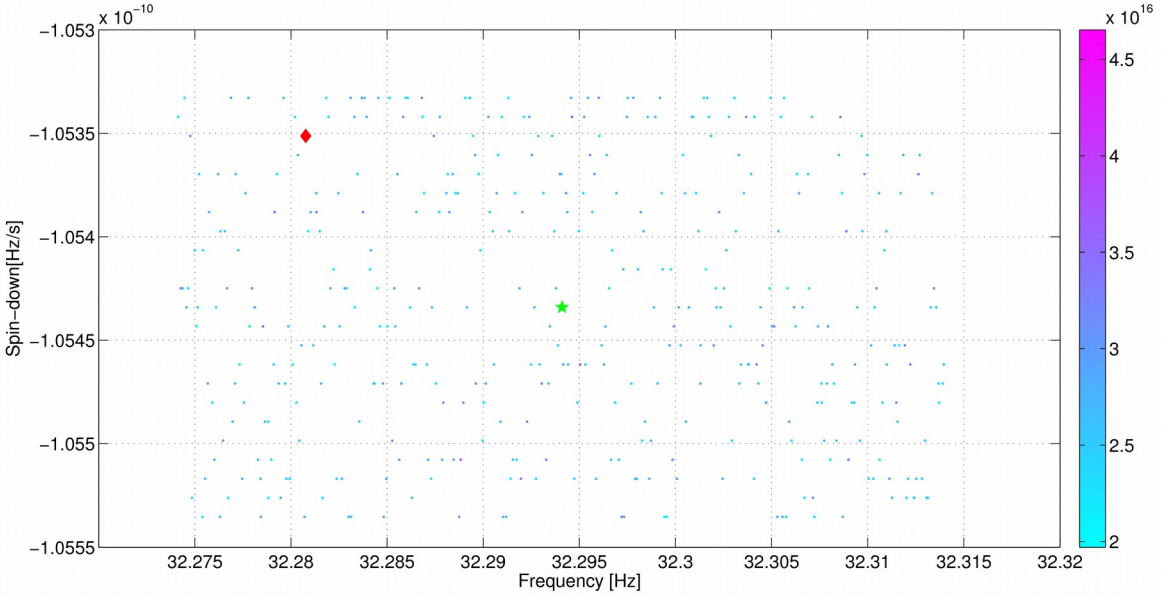


J1813-1749:

Likely due to an unidentified noise.

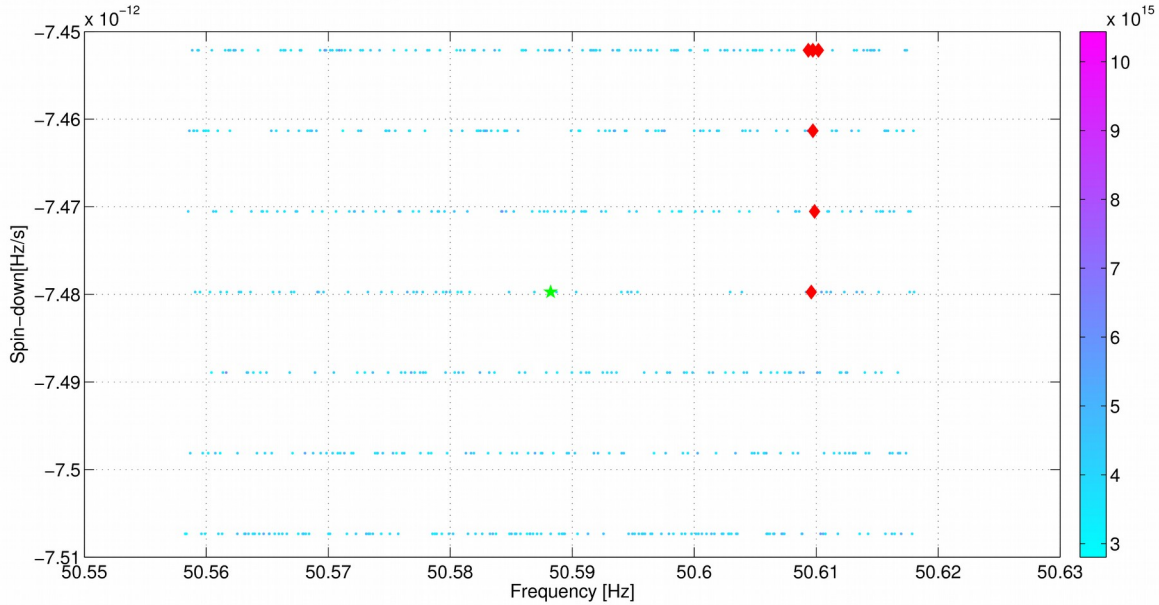
P-value ~ 10^{-6}

Candidates selection



J1833-1034:

	Freq[Hz]	SD [Hz/s]	P
C01	32.28076330	-1.0535e-10	0.0004

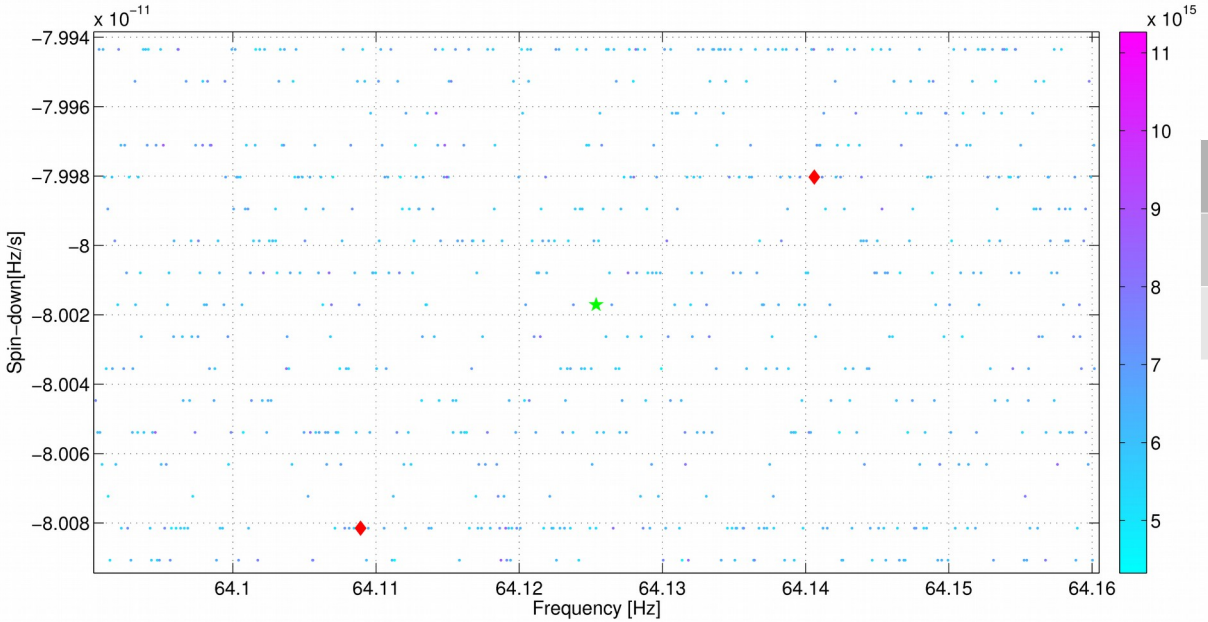


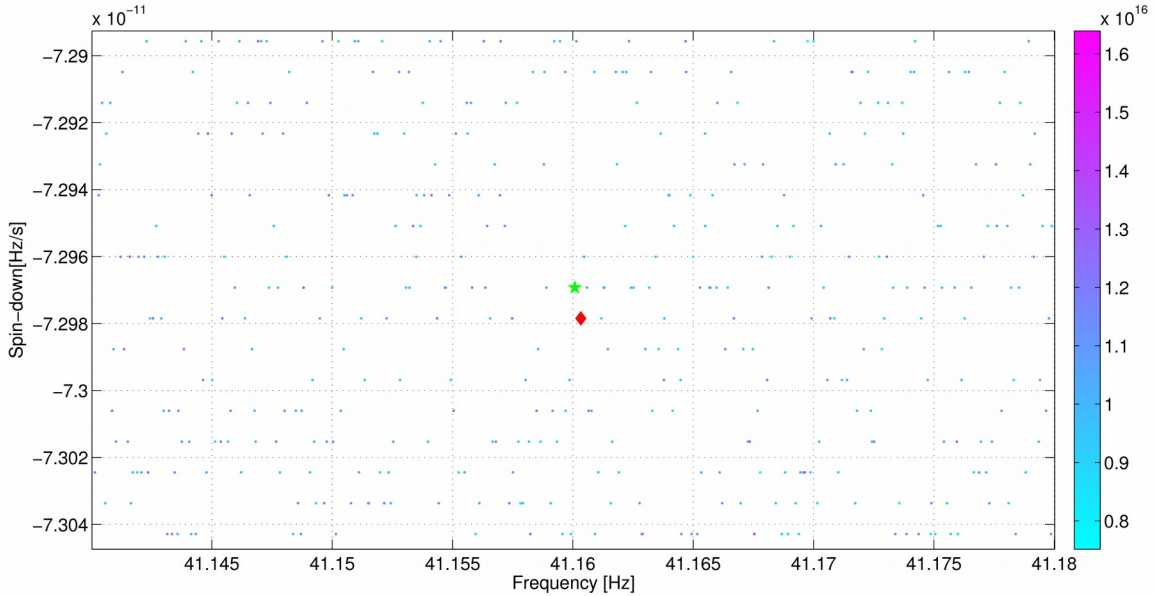
J1952+3252:

Likely due to an unidentified noise.

P-value ~ 10^{-5}

Candidates selection





J1400-6326:

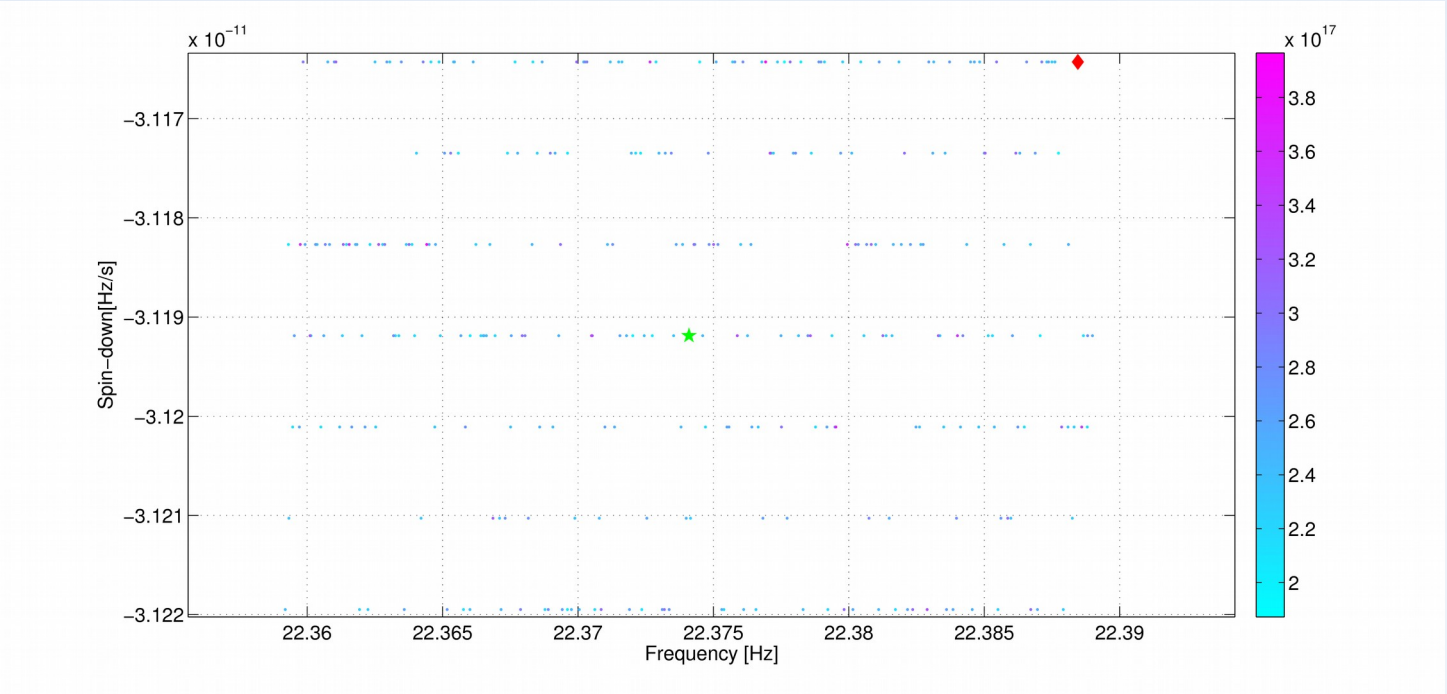
	Freq[Hz]	SD [Hz/s]	P
C01	64.10892531	-8.0081e-11	0.002
C02	64.14060108	-7.9980e-11	2e-4

J2022+3842_

	Freq[Hz]	SD [Hz/s]	P
C01	41.16033188	-7.2978e-11	0.007

Candidates selection

Vela:



	Freq[Hz]	SD [Hz/s]	P
C01	22.38845634	-3.1164e-12	0.009

Candidates selection

We have checked the nature of the candidates by:
1./ Checking the presence of noise lines in the neighborhood
2./ Check if the candidate is present in LHO and LLO alone.

	# candidates	Rejection Notes
Crab	*1*	Not in LHO, Present in LLO
J0205+6449	*1*	Not in LHO, not in LLO
J1813-1246	*2*	Not in LHO, not in LLO
J1813-1749	*36*	*Likely Noise Line in H-not identified**
J1833-1034	*1*	Not in LHO, not in LLO
J1952+3252	*6*	*Likely Noise Line in L-not identified **
J2043+2740	*0*	
J2229+6114	*0*	
Vela	*1*	Not in LHO, not in LLO
J1400-6326	*2*	Not in LHO, not in LLO
J2022+3842	*1*	Not in LHO, not in LLO

*https://wiki.ligo.org/viewauth/CW/O1LineCleaningInfo

Upper-limit

Assuming that our candidate are due to noise we can compute the upper-limits

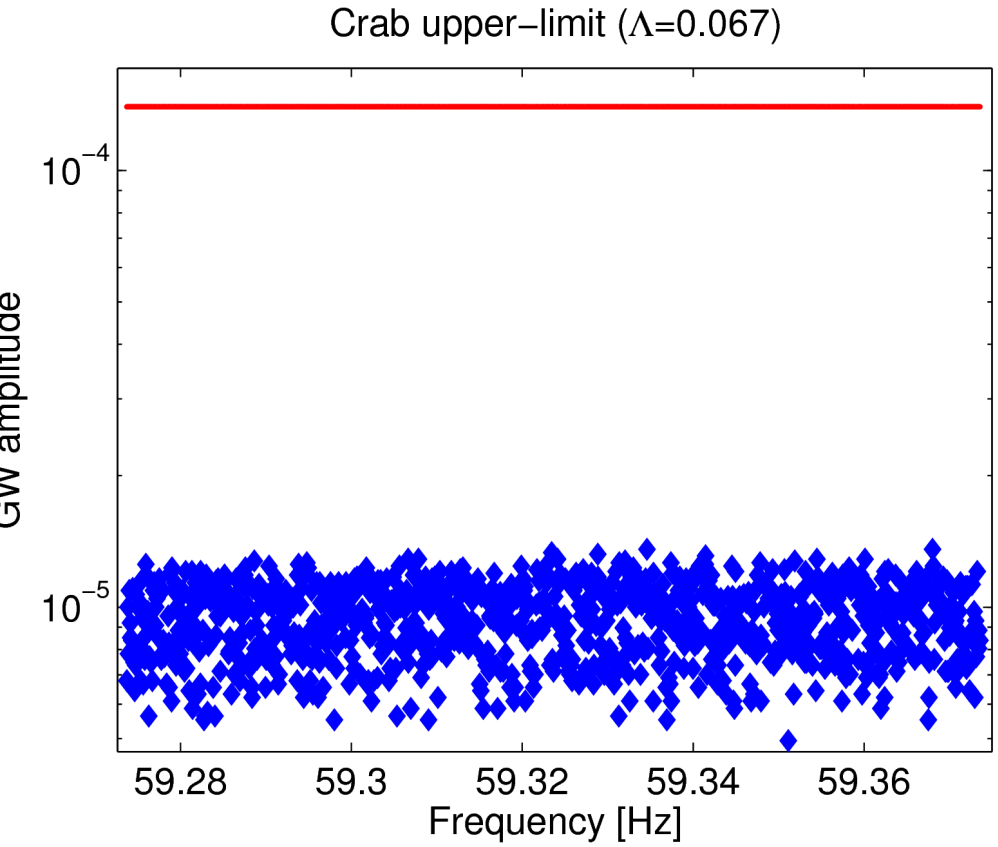
We have computed the upper-limits injecting directly the signals in the frequency domain (as 5-vectors), assuming that the spin-down a Doppler effect were already corrected

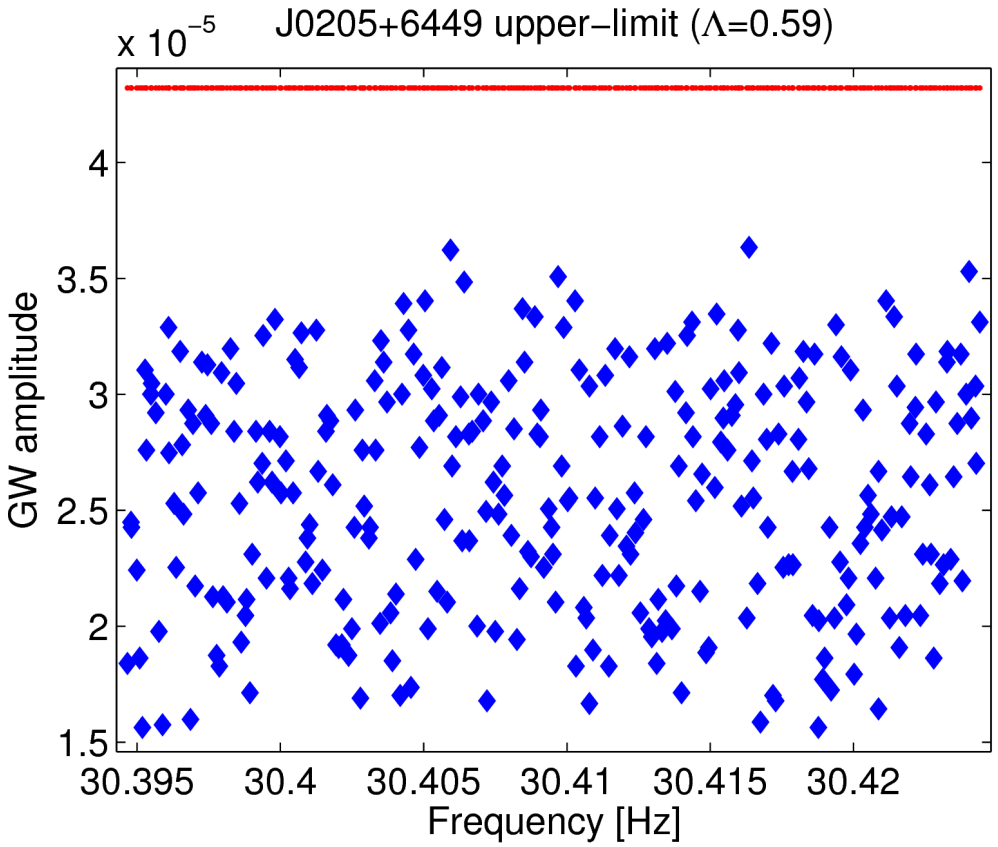
- We have taken into account that this choice can underestimate the upper-limits by a factor 15%

Then we have computed the upper-limits at 95 % confidence level

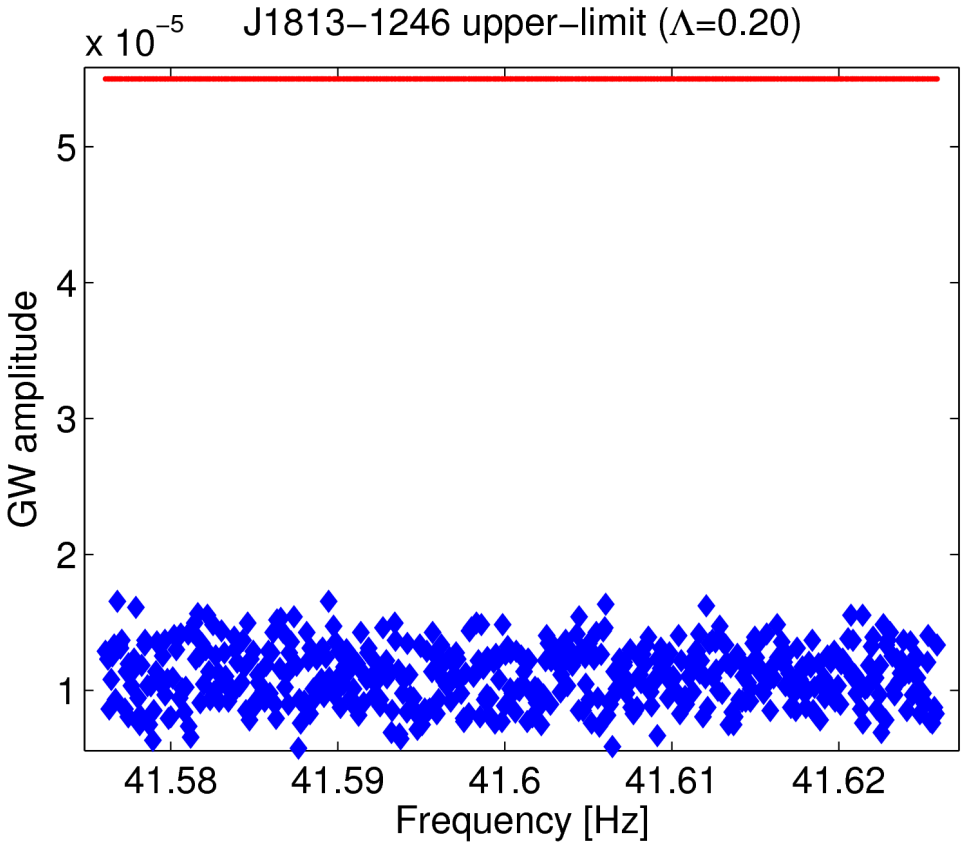
a new UL procedure has been developed and will be used to re-compute the UL (but we do not expect significant changes with respect to the numbers given here)

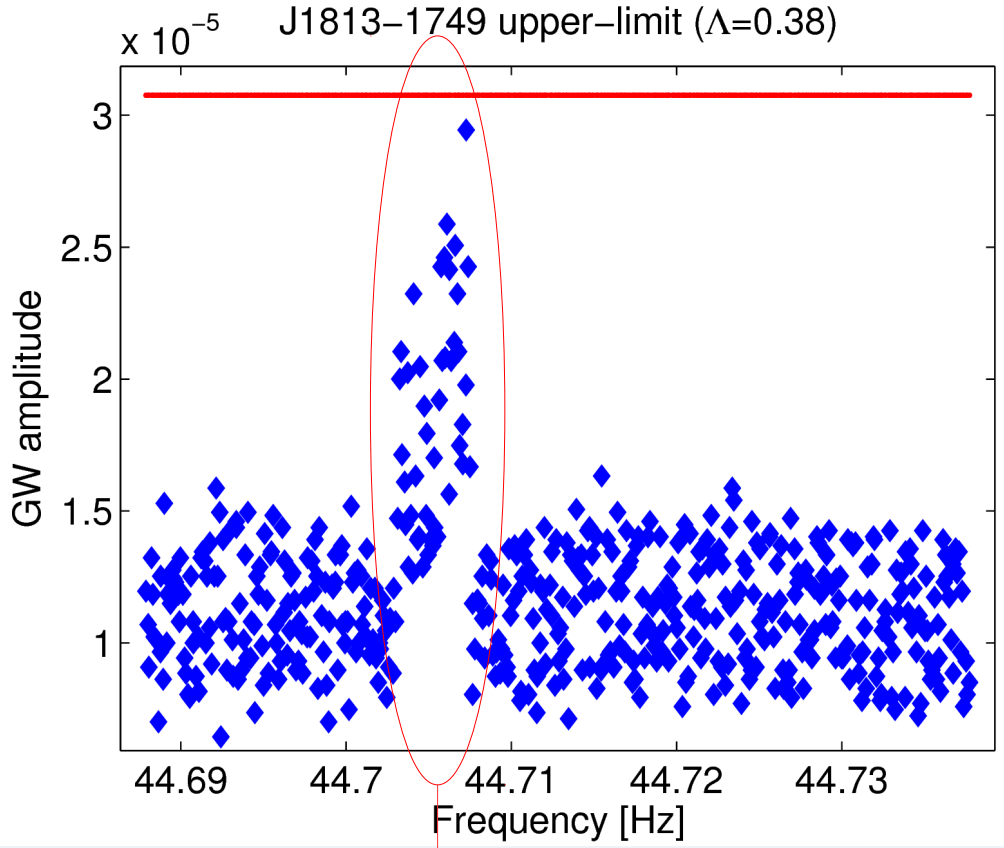
Upper-limit


Crab upper−limit (Λ=0.067)
GW amplitude
10^{-4}
10^{-5}
59.28
59.3
59.32
59.34
59.36
Frequency [Hz]


J0205+6449 upper−limit (Λ=0.59)
x 10^{-5}
GW amplitude
4
3.5
3
2.5
2
1.5
30.395
30.4
30.405
30.41
30.415
30.42
Frequency [Hz]

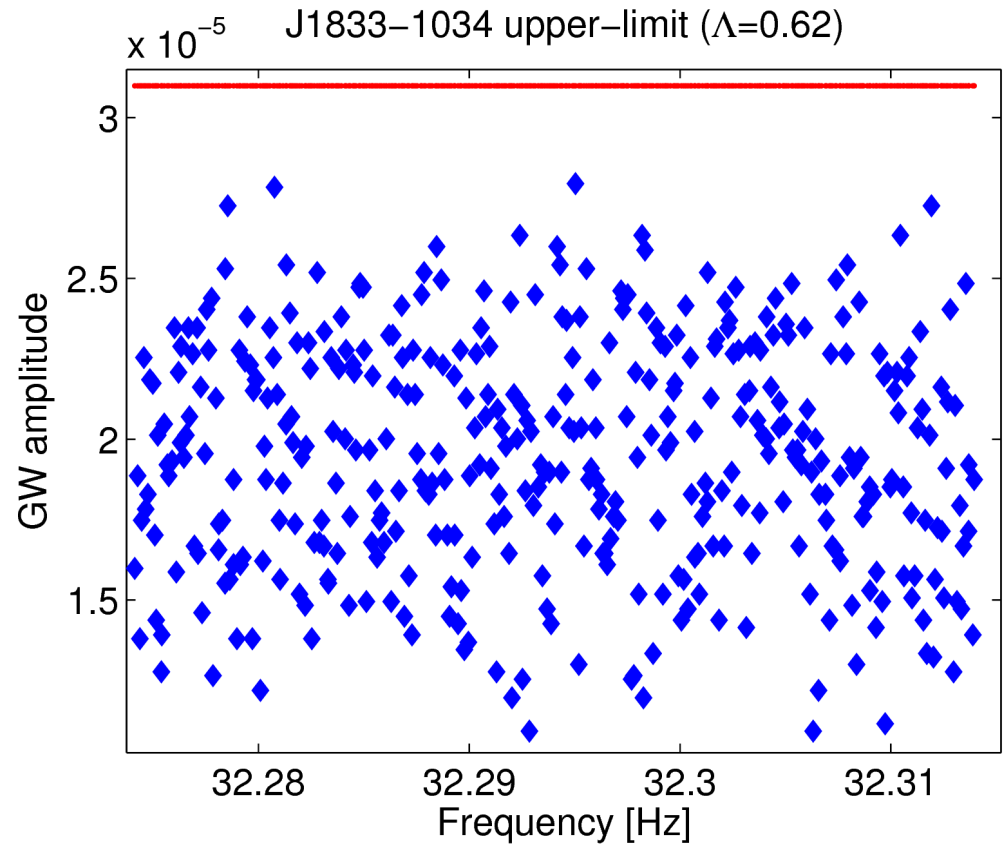
Upper-limit

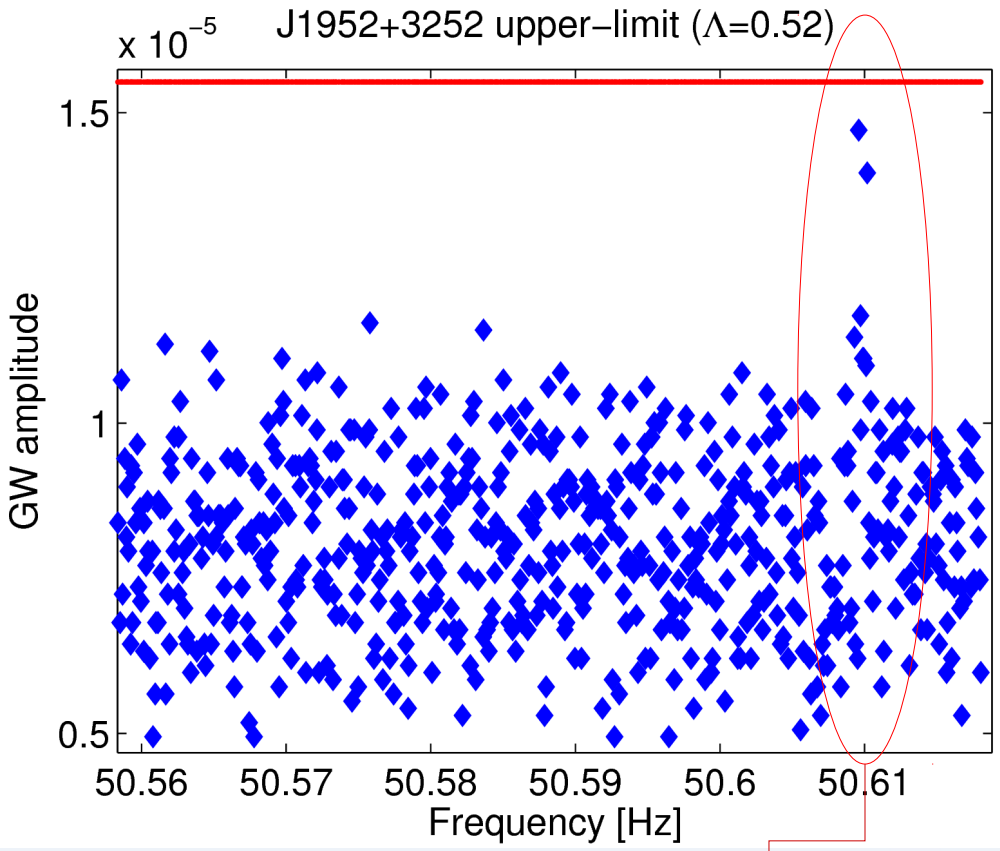




Noise line

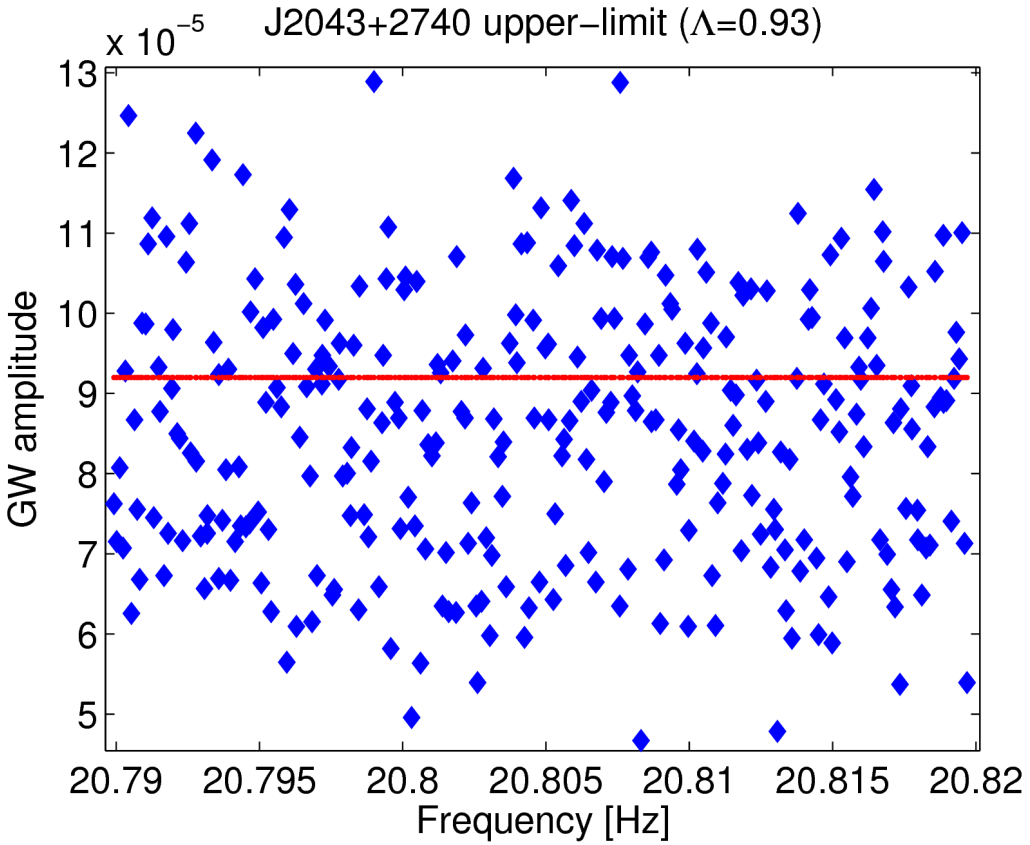
Upper-limit

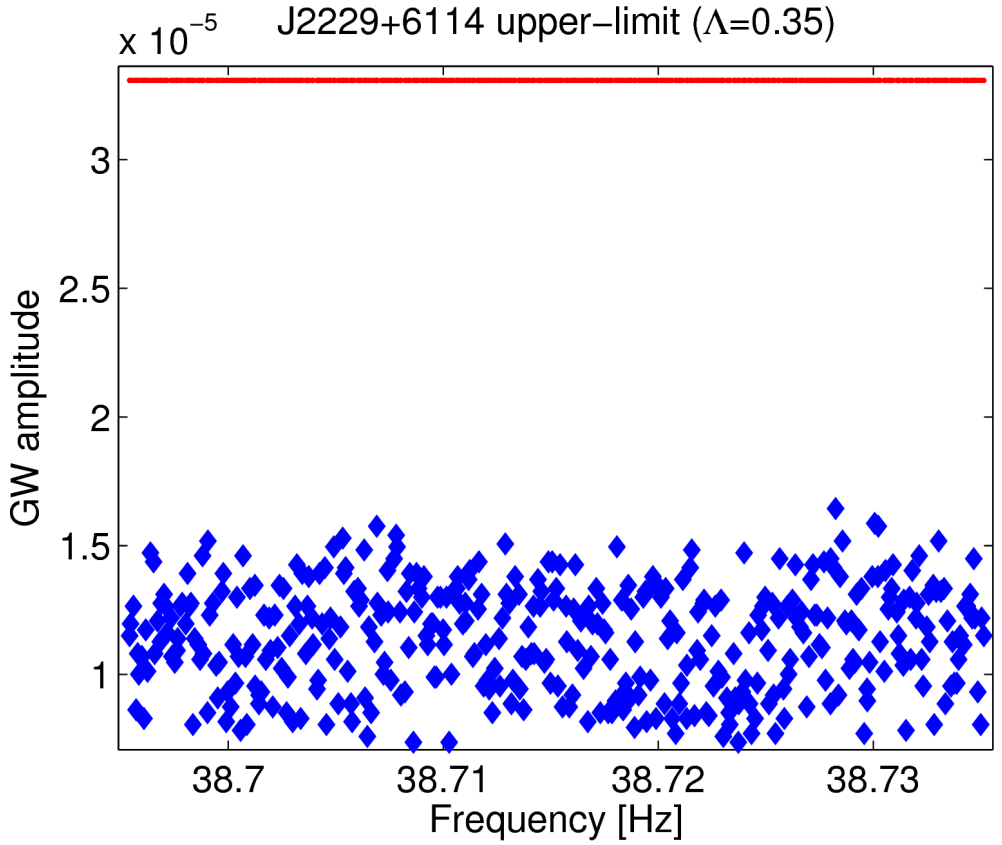




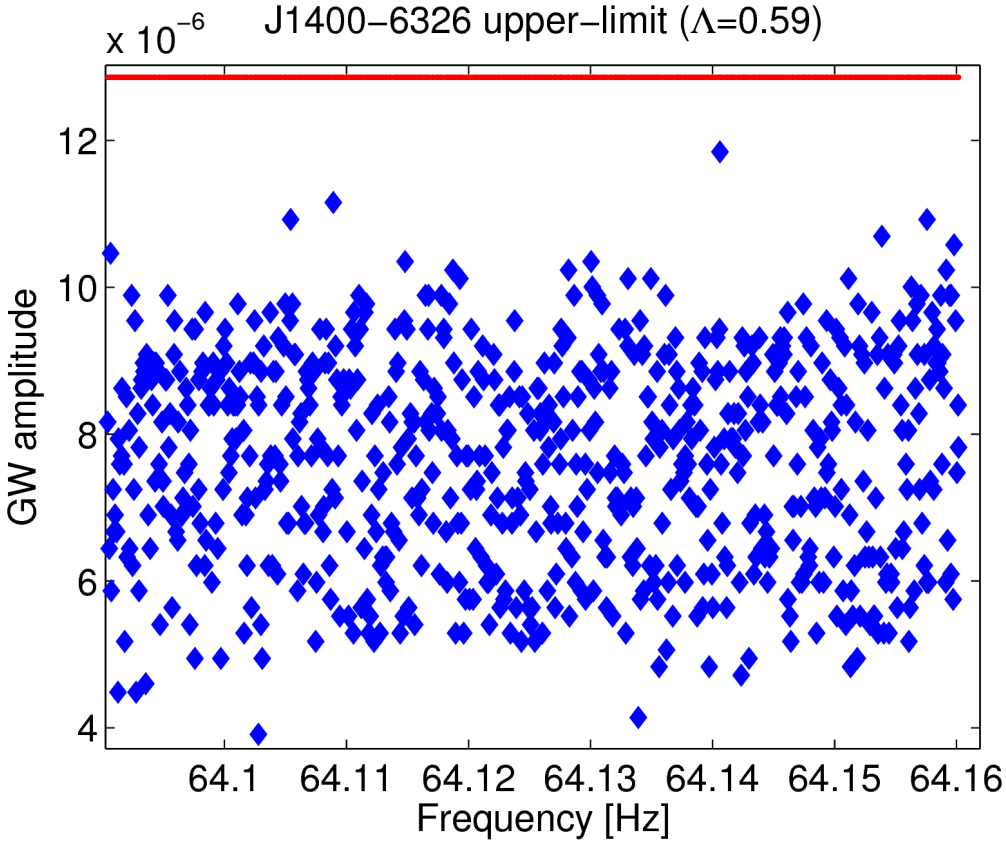
Noise line

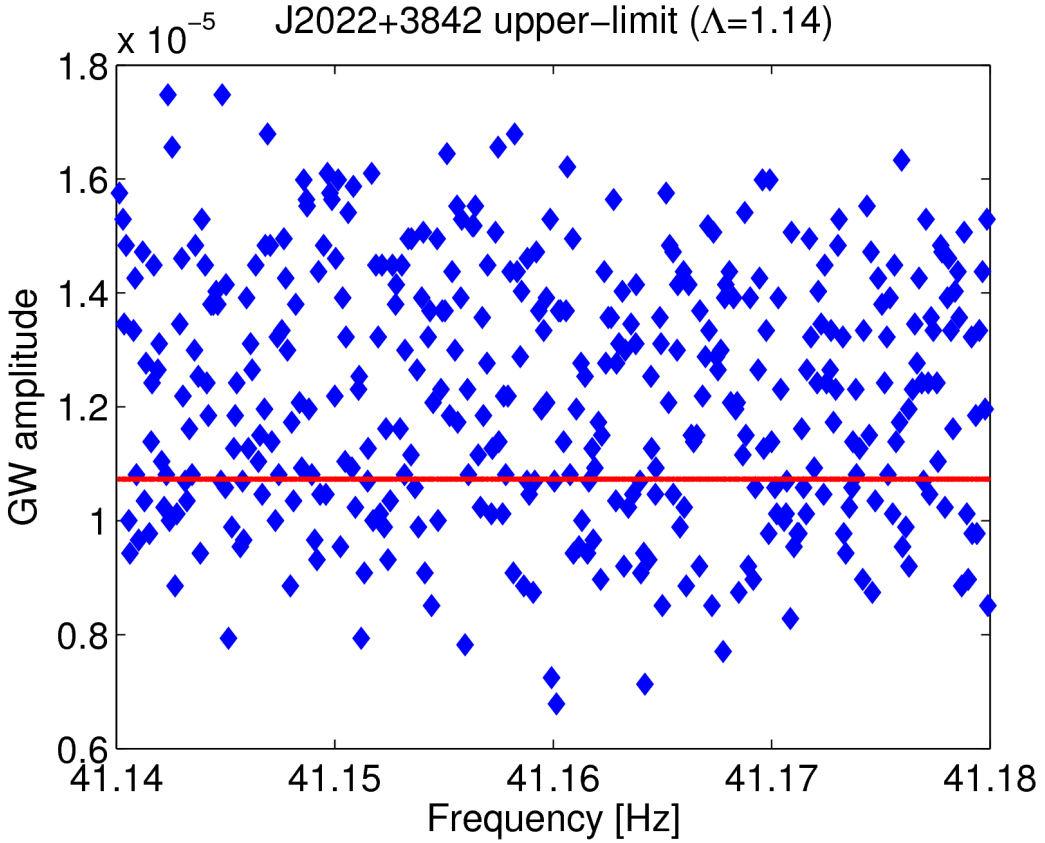
Upper-limit


J2043+2740 upper−limit (Λ=0.93)
x 10^−5
GW amplitude
Frequency [Hz]
13
12
11
10
9
8
7
6
5
20.79
20.795
20.8
20.805
20.81
20.815
20.82

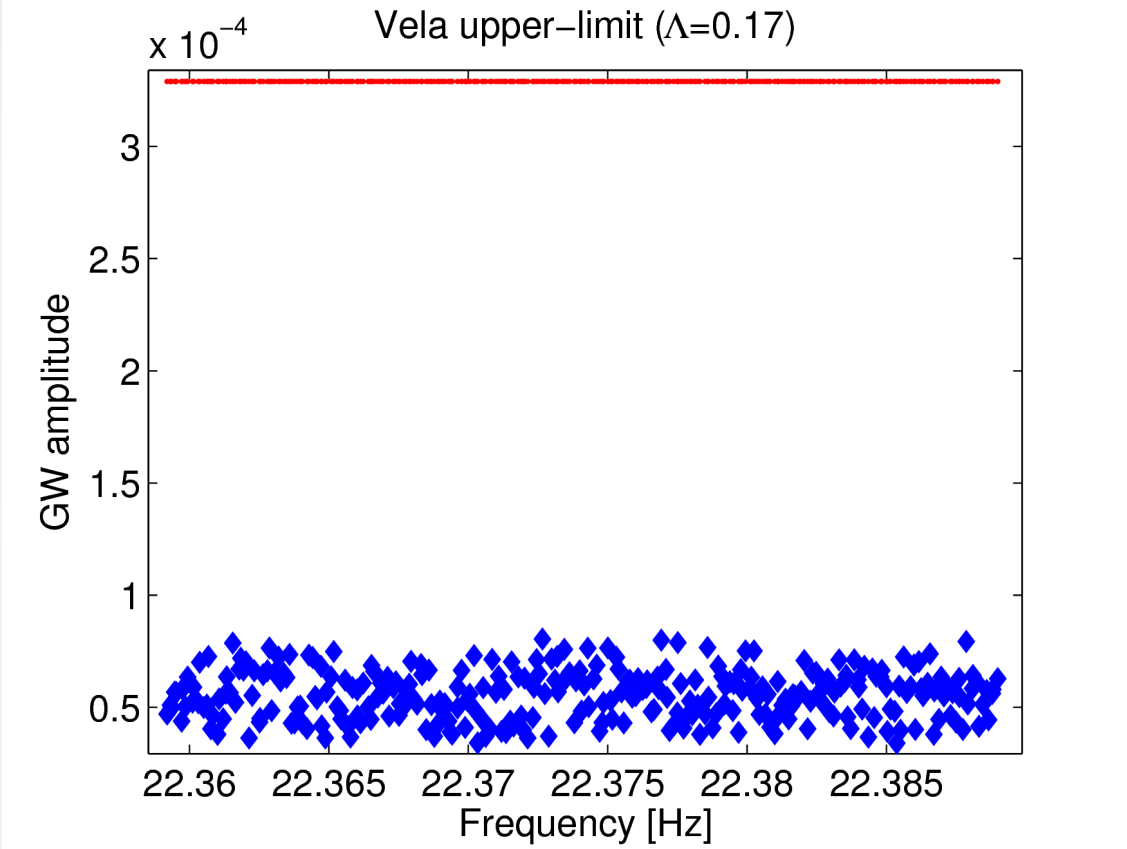

J2229+6114 upper−limit (Λ=0.35)
x 10^−5
GW amplitude
Frequency [Hz]
3
2.5
2
1.5
1
38.7
38.71
38.72
38.73

Upper-limit


x 10^−6
J1400−6326 upper−limit (Λ=0.59)
GW amplitude
12
10
8
6
4
64.1
64.11
64.12
64.13
64.14
64.15
64.16
Frequency [Hz]


x 10^−5
J2022+3842 upper−limit (Λ=1.14)
GW amplitude
1.8
1.6
1.4
1.2
1
0.8
0.6
41.14
41.15
41.16
41.17
41.18
Frequency [Hz]

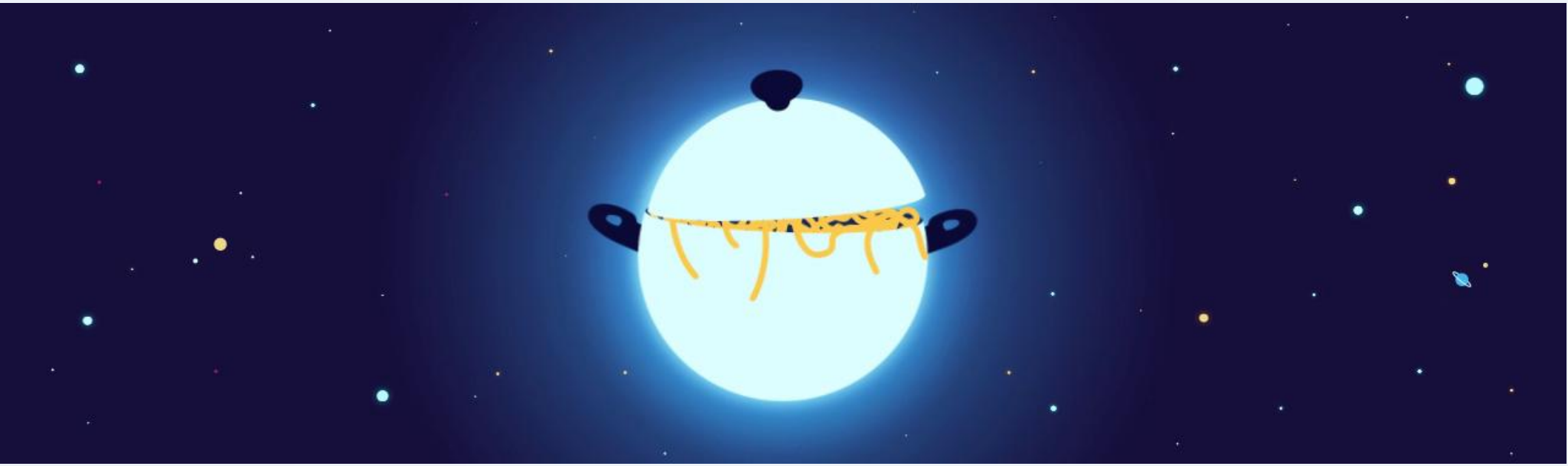
Upper-limit


Vela upper–limit (Λ=0.17)
x 10^−4
GW amplitude
3
2.5
2
1.5
1
0.5
22.36
22.365
22.37
22.375
22.38
22.385
Frequency [Hz]

What’s next?

- Proceed with the review work
- Compute the upper-limit with the complete procedure
- Look for other interesting pulsars...
- Develop a better candidates selection procedure
- Develop a faster method for Doppler correction (which is currently the bottleneck of the procedure)

Stay tuned!



Backup slides

Target pulsars and searched parameters

We select the frequency band around the GW expected value assuming a maximum mismatch of:

$$\Delta f = 2 f_0 \delta$$

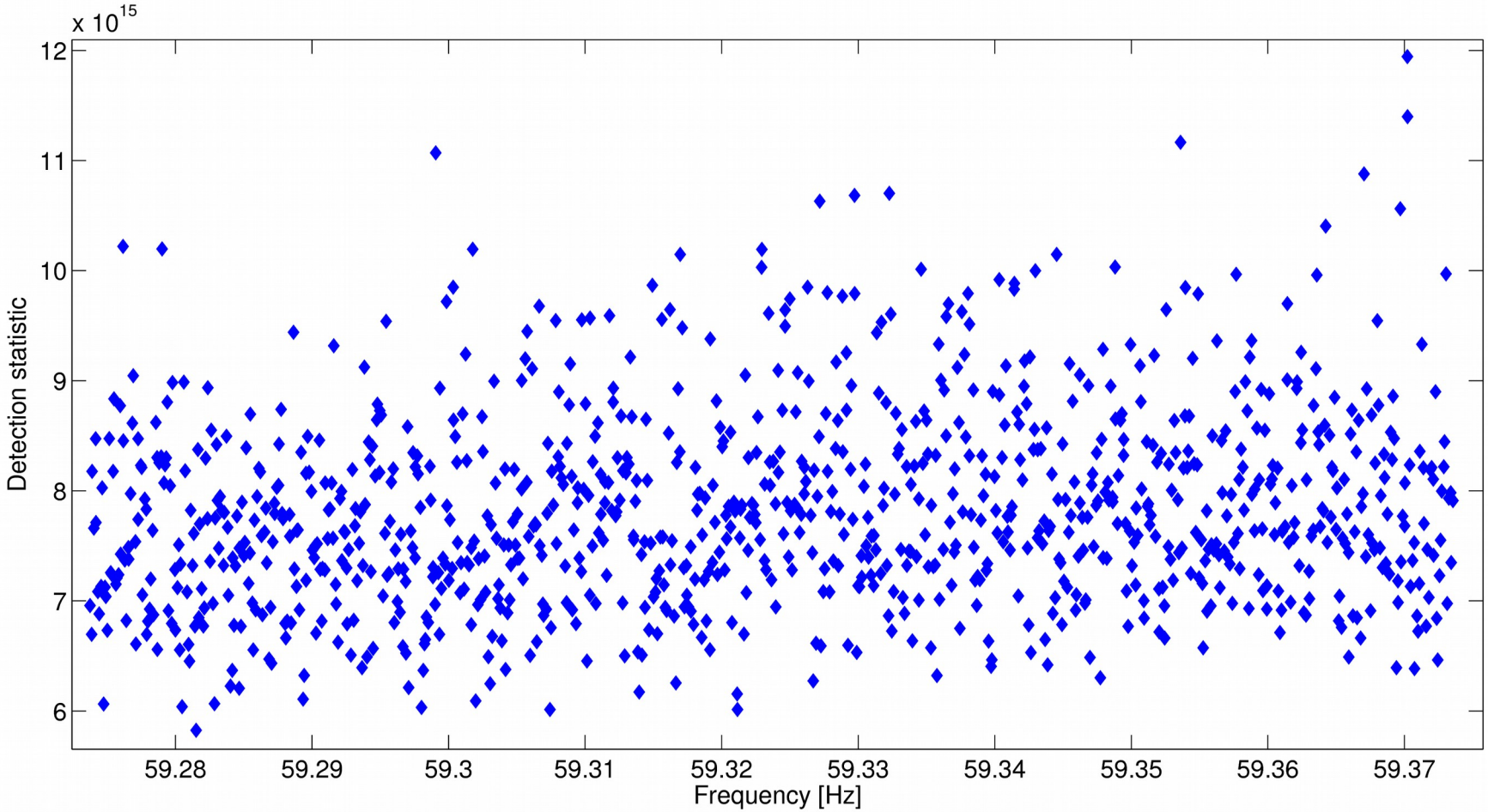
Typical values of δ are ~ 10^{-3}

The spin-down's bands are then selected differentiating the relation above and keeping δ as a constant

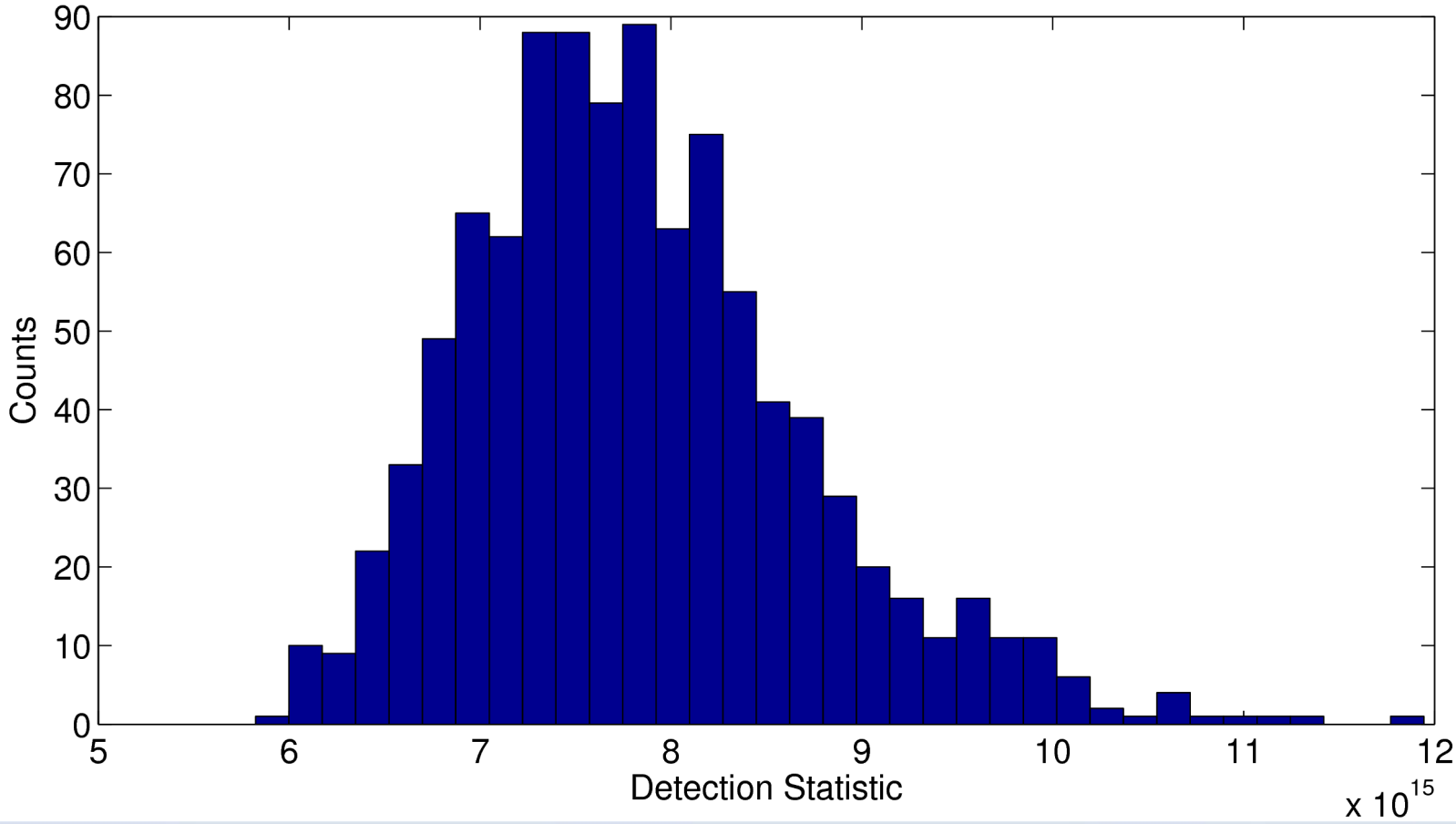
$$\Delta \dot{f} = 2 \dot{f}_0 \delta$$

$$\Delta \ddot{f} = 2 \ddot{f}_0 \delta$$

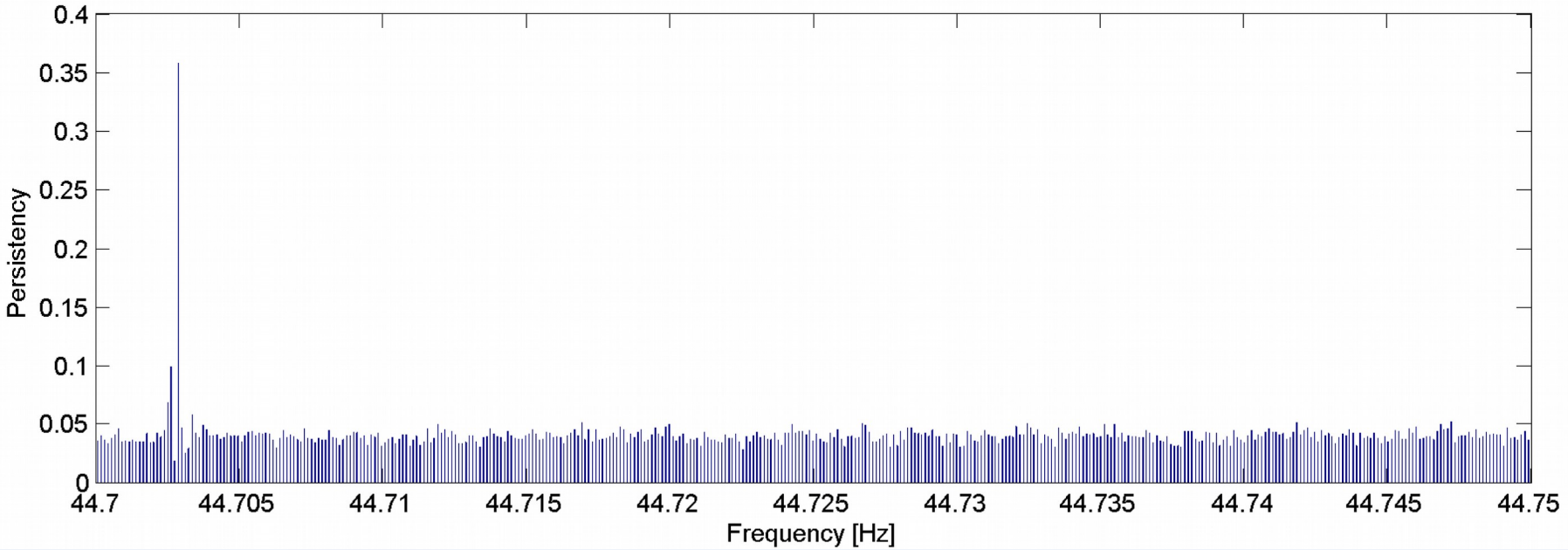
Local maximums of the detection statistic: Fluctuations (Crab)



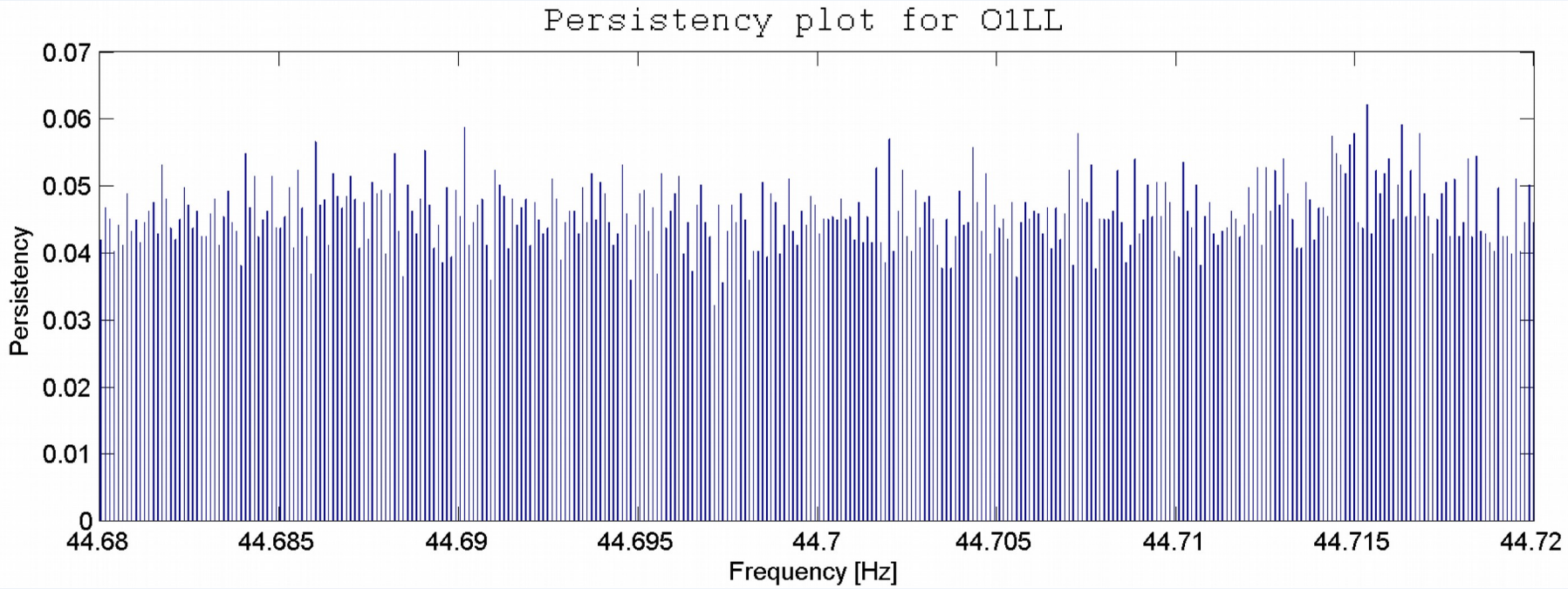
Local maximums of the detection statistic: histogram(Crab)
Mean: 7.8 e15
STD=8.92e14



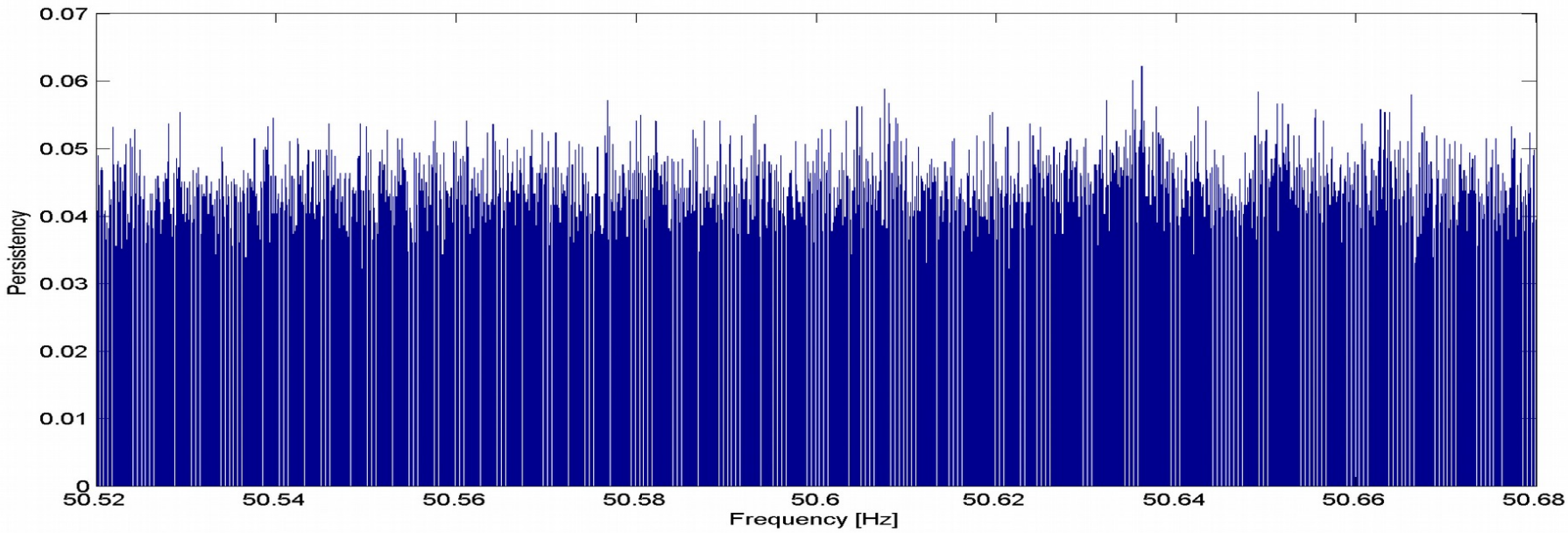
Hanford persistency plot: Not identified noise line @ 44.703 Hz



Livingstone persistency plot: There is no 44.703 Hz noise line



Hanford persistency plot: Not identified noise line @ 59.604 Hz



Livingstone persistency plot: Not identified noise line @ 59.604 Hz