Projects of the University of Białystok

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POLGRAW General Meeting

Kraków, October 15–16, 2026

1 Group Members

2 Projects

1 Group Members

2 Projects

Members of the POLGRAW Group

University of Białystok, Faculty of Physics:

- prof. dr hab. Piotr Jaranowski,
- dr Andrzej Pisarski,
- mgr Ernest Głowacki (PhD student).

1 Group Members

2 Projects

Projects

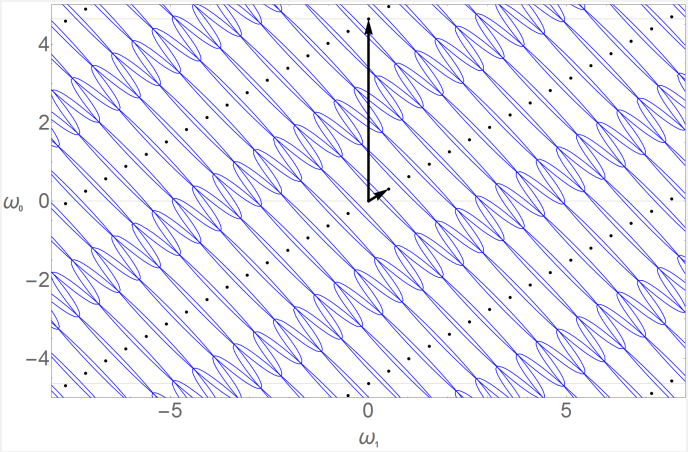
- Narrow-band time-domain $\mathcal{F}$-statistic-based pipeline for CW searches from known pulsars.
- Generation of efficient grids of templates in the space of parameters of CW GW signals for all types of searches (narrow-band targeted, directed, all-sky).
- LVK-related outreach.

Generation of Efficient Grids of Templates (1/2)

Andrzej Pisarski (Piotr Jaranowski, Andrzej Królak)

- One assumes that the search algorithm is based on the time-domain $\mathcal{F}$-statistic and one considers narrow-band searches with several spindown parameters included.
- One employs isoheights of the signal-free autocovariance function of the $\mathcal{F}$-statistic computed for the simplified model of the GW signal (with constant amplitude and phase which is a linear function of parameters).
- Grids of templates are suitable for all-sky, directed, and narrow-band targeted searches.
- They enable the usage of the fast Fourier transform (FFT) in the computation of the $\mathcal{F}$-statistic.
- In the case of all-sky searches, they enable efficient resampling of data to barycentric time (so it is enough to do resampling only once per sky position for all spindown values).
- Constructions of the grids are implemented in the computer program `GridsGenerator` written by Andrzej Pisarski and freely available on `GitHub` at https://github.com/apisarski/gridgen.

Generation of Efficient Grids of Templates (2/2)



NB TD $\mathcal{F}$-statistic-based Pipeline for CW Searches from Known Pulsars (1/5)

Ernest Głowacki, Piotr Jaranowski, Andrzej Pisarski, Andrzej Królak

- NB targeted searches — known position of the source in the sky; frequency and spindowns are searched for in the narrow ranges around the values known from the electromagnetic observations.
- Why narrow-band searches?

  There are a few reasons to carry out narrow-band searches instead of targeted searches. All these can modify the expected GW frequency:
  - the available time-evolution of the neutron star's phase (i.e., the star's ephemerides) can be outdated;
  - the neutron star may weakly precess;
  - there might be a mismatch between the rotational rates of different layers of the neutron star (the crust and the core rotate at slightly different rates, and a core asymmetry dominates the GW emission).

NB TD $\mathcal{F}$-statistic-based Pipeline for CW Searches from Known Pulsars (2/5)

- Ranges of the frequency and spindown parameters:

$$f_{\mathrm{gw}} \in 2f_{\mathrm{em}}\langle 1-\delta, 1+\delta\rangle,$$

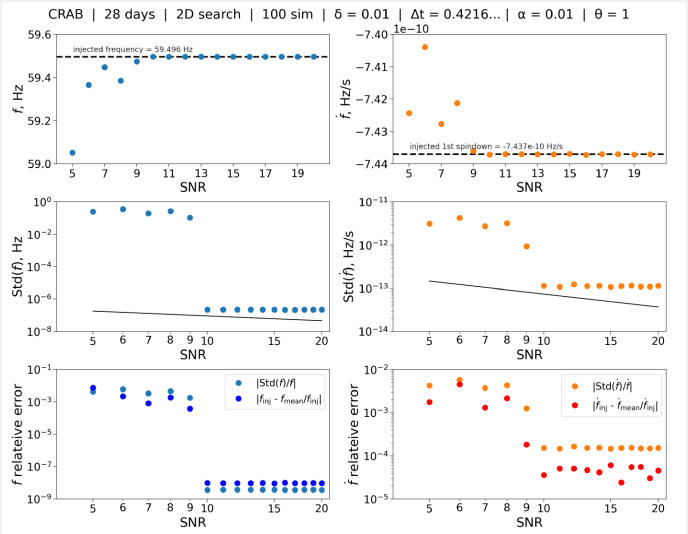
$$\dot{f}_{\mathrm{gw}} \in 2\dot{f}_{\mathrm{em}}\langle 1-\delta, 1+\delta\rangle, \qquad 10^{-3} \leq \delta \leq 10^{-2}.$$

$$\ddot{f}_{\mathrm{gw}} \in 2\ddot{f}_{\mathrm{em}}\langle 1-\delta, 1+\delta\rangle,$$

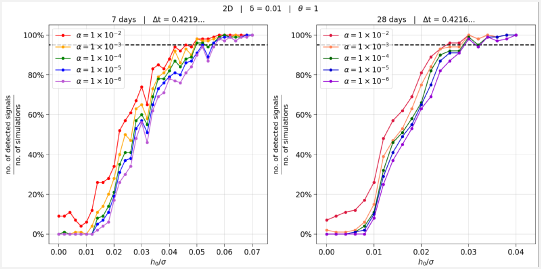
- Fixing the offset frequency (used to shift the signal to a lower frequency band) and the sampling rate (i.e., the Nyquist frequency) takes into account the ephemerides of a pulsar (with frequency smearing caused by spindowns) and δ.
- The threshold $\mathcal{F}_0(\alpha, N_c)$ for the $\mathcal{F}$-statistic is computed from the assumed false alarm probability α and the number N_c of independent cells in the parameter space (such that the values of the $\mathcal{F}$-statistic in different cells can be considered as independent random variables).

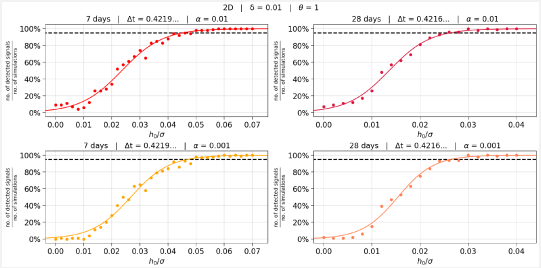
NB TD $\mathcal{F}$-statistic-based Pipeline for CW Searches from Known Pulsars (3/5)

- We use grids of templates generated by the `GridsGenerator` program.
- The $\mathcal{F}$-statistic is computed at each grid's node after resampling the data to the SSB (using the nearest neighbour interpolation) and applying the FFT algorithm.
- The sensitivity of the pipeline (and upper limits in the case of nondetection) is assessed by injecting GW signals with randomly chosen parameters (for a fixed GW amplitude) and recording the fraction of detected signals.
- The pipeline is written in python.
- The pipeline is almost complete. We conducted extensive simulations using Gaussian noise (presentations at LVK meetings in fall 2025 and fall 2026).
- In the coming months, we want to analyse (public) O4a data for several known pulsars.


CRAB | 28 days | 2D search | 100 sim | δ = 0.01 | Δt = 0.4216... | α = 0.01 | θ = 1
injected frequency = 59.496 Hz
f, Hz
SNR
1e−10
injected 1st spindown = −7.437e-10 Hz/s
ḟ, Hz/s
Std(f̂), Hz
Std(ḟ̂), Hz/s
|Std(f̂)/f|
|f̂inj - f̂mean/f̂inj|
f relateive error
|Std(ḟ̂)/ḟ|
|ḟ̂inj - ḟ̂mean/ḟ̂inj|
ḟ relateive error

NB TD $\mathcal{F}$-statistic-based Pipeline for CW Searches from Known Pulsars (5/5)





		observation time	
		7 days	28 days
α	θ	$h_0^{95\%}/\sigma$	
10^{-2}	1	0.0451(11)	0.02615(61)
	1.2092	0.0453(11)	0.02622(59)
10^{-3}	1	0.0470(11)	0.02638(73)
	1.2092	0.0472(11)	0.02633(71)
10^{-4}	1	0.0488(11)	0.02765(85)
	1.2092	0.0494(11)	0.02789(82)
10^{-5}	1	0.0515(12)	0.02868(80)
	1.2092	0.0517(12)	0.02875(81)
10^{-6}	1	0.0537(14)	0.02981(81)
	1.2092	0.0541(14)	0.03000(82)

LVK-related Outreach

Piotr Jaranowski

- Translation of current LVK-related documents into Polish.
- Translation of the English Wikipedia page about the Virgo detector into Polish (work has just begun).