

NCAC Annual Meeting

Przemysław Figura

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Time Domain F-statistic analysis

- Search for continuous gravitational waves, *i.e.* for long lasting nearly monochromatic gravitational signals. Typically emitted by rotating, non-axisymmetric neutron stars.
- Detection method based on finding maximum of a likelihood function with respect to the signal parameters.
- F-statistic, \mathcal{F} , is a match filter of detector signal with model signal. It depends on following parameters:
 - ▶ signal frequency (f),
 - ▶ signal spindown (\dot{f}),
 - ▶ source sky position – right ascension (α),
 - ▶ source sky position – declination (δ),
 - ▶ an angle between total angular momentum of the source and the direction from the source to Earth (ι),
 - ▶ signal polarisation angle (ψ),
 - ▶ signal phase shift (Φ).

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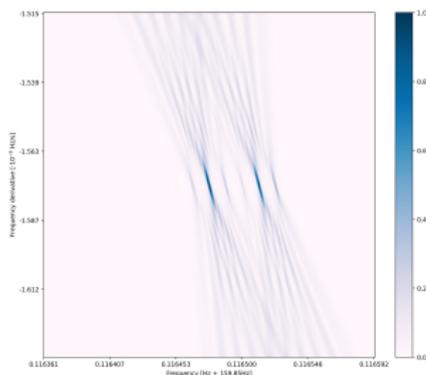
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 - ▶ ~~signal polarisation angle (ψ); ← minor impact, meh...~~
 - ▶ ~~signal phase shift (Φ); ← minor impact, meh...~~

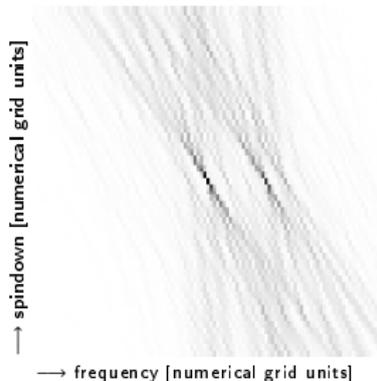
Example images

- We obtain images from TDFstat All Sky pipeline using 6 days long time segments.
- We simulate detector noise with Gaussian noise in time domain (which becomes χ^2 -noise in F-statistic domain).
- We use signal software injections simulating real hardware injections.

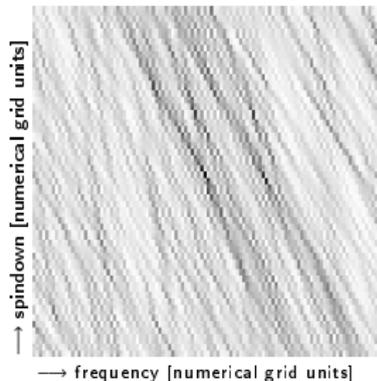
Modelled signal image:



Signal image from TDFstat code:

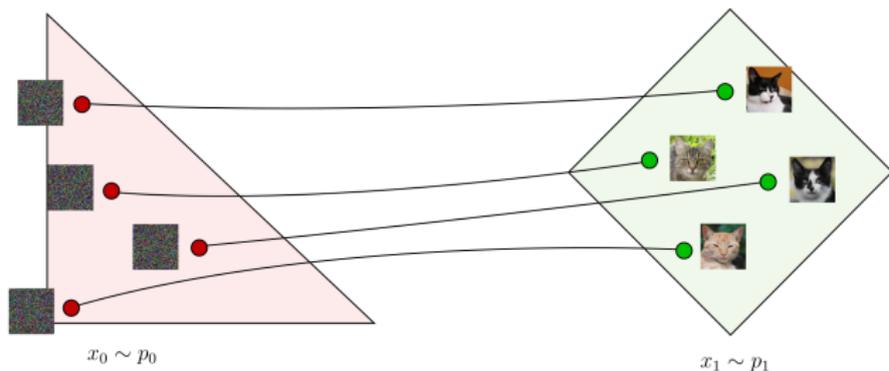


Signal with noise image from TDFstat code:



α -(de)Blending model

α -(de)Blending is a deterministic diffusion model which allows us to compute a mapping between samples of two distributions. Works on χ^2 -noise images!

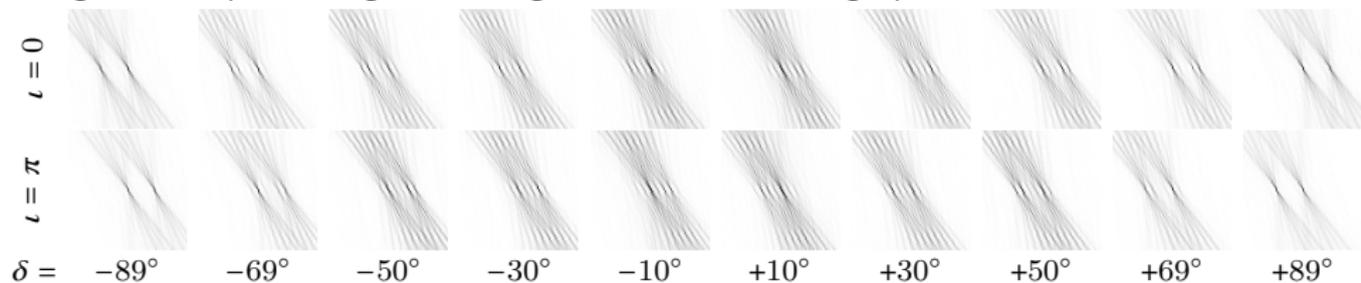


Linear samples interpolation:

$$x_\alpha = (1 - \alpha) x_0 + \alpha x_1$$

Training image sets

Signals set (356 images with signal + 89 blank images):



Noise set (46750 images of χ^2 -noise with 4 degrees of freedom):



Inference

Considered signal injections:

Pulsar name	α [rad]	δ [rad]	frequency [Hz]	spindown [Hz/s]	$\cos(\iota)$	Number of days for SNR = 5	SNR at 6 days
Pulsar00	1.249	-0.981	265.58	$-4.15 \cdot 10^{-12}$	0.795	10	3.9
Pulsar02	3.757	0.060	575.16	$-1.37 \cdot 10^{-13}$	-0.929	10	3.9
Pulsar03	3.113	-0.584	108.86	$-1.46 \cdot 10^{-17}$	-0.081	10	3.9
Pulsar05	5.282	-1.463	52.81	$-4.03 \cdot 10^{-18}$	0.463	1	12.2
Pulsar10	3.867	0.748	26.33	$-8.50 \cdot 10^{-11}$	-0.988	1	12.2
Pulsar11	4.976	-1.017	31.42	$-5.07 \cdot 10^{-13}$	-0.329	10	3.9

For each pulsar we inject its signal into the noise for 4000 times and obtain that many images of different *signal+noise* instances, then we deblend obtained images. For reference we also deblend 4000 images of *just noise* instance.

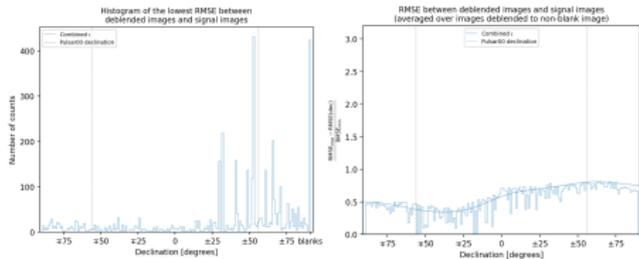
Note:

In our case, if F-statistic depends only on δ and ι , we have:

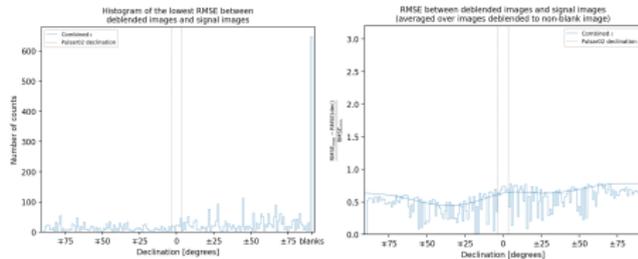
$$\mathcal{F}(\delta, \iota) \approx \mathcal{F}(-\delta, \iota + \pi)$$

Inference

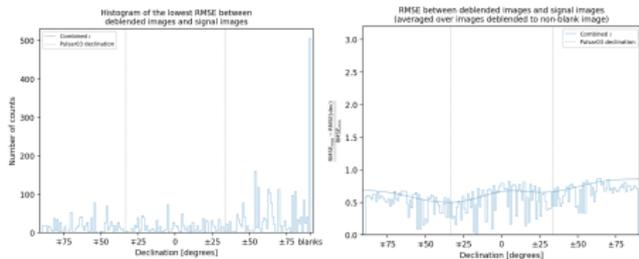
Pulsar00 (SNR = 3.9)



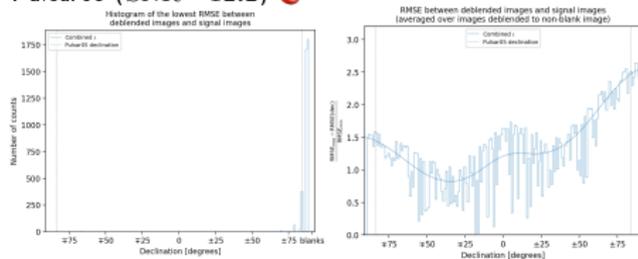
Pulsar02 (SNR = 3.9)



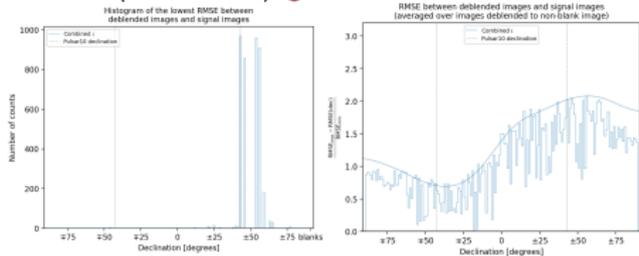
Pulsar03 (SNR = 3.9)



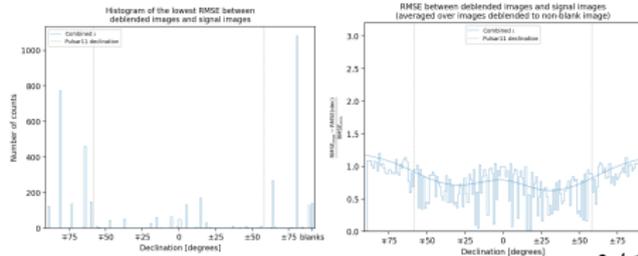
Pulsar05 (SNR = 12.2)



Pulsar10 (SNR = 12.2)



Pulsar11 (SNR = 3.9)



Thank you. :-)