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One scheme for Optimization of Pulsar Timing Arrays

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Acknowledgments

- The NANOGrav detection working group

Brief recap of Burt, Lommen & Finn (2011) results

- Burt, Lommen and Finn (2011): spend MORE time on the best pulsars, and LESS time on the worst pulsars.
- Analysis assumed $$\sigma = \frac{\sigma_0}{\sqrt{T}}$$
- Ryan Anella's analysis adds realistic noise floor, and optimization results under various conditions.

This particular optimization optimizes for signal to noise. For use with a

The S/N ratio, ρ, for one pulsar is just

$$\rho = \frac{\tau}{\sigma}$$

τ : GW signal in that pulsar

σ : pulsar noise (rms).

Sum that up for all pulsars…

$\hat{k}$: GW direction

$\hat{n}_j$: pulsar direction

N_p : number of pulsars in array

$$\overline{\rho^2(\hat{k})} \propto \sum_{j=1}^{N_p} \left(\frac{1 - \hat{k} \cdot \hat{n}_j}{\sigma_j} \right)^2$$

σ_j is the thing we get to jigger…

$$\sigma = \frac{\sigma_0}{\sqrt{T}}$$

Not really fair...

Instead :

$$\sigma^2 = \frac{\sigma_0^{\,2}}{T} + Floor^2$$

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Results for Current NANOGrav Array

	TimeSpent (%)
	17 Pulsars + Isotropic GWs
Pulsar Name	10 ns
J0030+0451	0
J0613-0200	0
J1012+5307	0
J1455-3330	0
J1600-3053	0
J1640+2224	0
J1643-1224	0
J1713+0747	52.56
J1744-1134	0
J1853+1308	0
B1855+0900	0
J1909-3744	47.44
J1910+1256	0
J1918-0642	0
B1953+2900	0
J2145-0750	0
J2317+1439	0
Overall / Current PTA (1)	**8.98**

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Results for Current NANOGrav Array

	TimeSpent (%)	
	17 Pulsars + Isotropic GWs	
Pulsar Name	10 ns	80%
J0030+0451	0	3.87
J0613-0200	0	1.47
J1012+5307	0	0.30
J1455-3330	0	0
J1600-3053	0	4.42
J1640+2224	0	0
J1643-1224	0	0
J1713+0747	52.56	39.79
J1744-1134	0	3.27
J1853+1308	0	1.73
B1855+0900	0	8.30
J1909-3744	47.44	29.93
J1910+1256	0	0
J1918-0642	0	3.05
B1953+2900	0	0
J2145-0750	0	2.71
J2317+1439	0	1.17
Overall / Current PTA (1)	**8.98**	**1.56**

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Do we really expect the sources to be isotropically distributed?

- Vikram Ravi: No.
- Joe Simon: No.

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Optimize for a source toward virgo – how much does distribution

		TimeSpent (%)			
		17 Pulsars + Isotropic GWs		17 Pulsars + GWs only from Virgo	
Pulsar Name	Angle from Virgo Cluster (Deg)	10 ns	80%	10 ns	80%
J0030+0451	162.42	0	3.87	0	0
J0613-0200	93.85	0	1.47	0	3.12
J1012+5307	48.48	0	0.30	0	4.08
J1455-3330	58.12	0	0	0	0
J1600-3053	67.18	0	4.42	0	7.14
J1640+2224	60.67	0	0	0	1.16
J1643-1224	68.26	0	0	0	0
J1713+0747	70.34	52.56	39.79	85.73	51.35
J1744-1134	82.29	0	3.27	0	3.72
J1853+1308	93.30	0	1.73	0	1.23
B1855+0900	94.76	0	8.30	0	6.83
J1909-3744	105.98	47.44	29.93	14.27	20.09
J1910+1256	97.36	0	0	0	0
J1918-0642	103.86	0	3.05	0	1.29
B1953+2900	101.89	0	0	0	0
J2145-0750	139.89	0	2.71	0	0
J2317+1439	147.61	0	1.17	0	0
Overall / Current PTA (1)		**8.98**	**1.56**	**10.13**	**1.63**

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What if you add a pulsar in the direction o Virgo?

Pulsar Name	Angle from Virgo Cluster (Deg)	TimeSpent (%) 17 + 1 Pulsars +Isotropic GWs 10 ns	17 + 1 Pulsars +Isotropic GWs 80%	17 +1 Pulsars + GWs only from Virgo 10 ns	17 +1 Pulsars + GWs only from Virgo 80%
J0030+0451	162.42	0	2.28	0	0
J0613-0200	93.85	0	1.21	0	0.87
J1012+5307	48.48	0	0.09	0	1.47
J1455-3330	58.12	0	0	0	0
J1600-3053	67.18	0	2.99	0	3.36
J1640+2224	60.67	0	0	0	0
J1643-1224	68.26	0	0	0	0
J1713+0747	70.34	38.19	30.53	31.22	30.82
J1744-1134	82.29	0	1.94	0	1.24
J1853+1308	93.30	0	0.72	0	0
B1855+0900	94.76	0	5.71	0	3.17
J1909-3744	105.98	26.46	22.04	0	11.41
J1910+1256	97.36	0	0	0	0
J1918-0642	103.86	0	1.67	0	0
B1953+2900	101.89	0	0	0	0
J2145-0750	139.89	0	1.33	0	0
J2317+1439	147.61	0	0.23	0	0
J1227+1243	0	35.34	29.25	68.78	47.67
Optimized/Unoptimized		6.97	1.54	9.46	1.66
Optimized 18 - Pulsar Array / Optimized 17 - Pulsar Array		**1.37**	**1.75**	**4.11**	**4.49**

Conclusion

- There are some pulsars we should be spending more time on, at the exclusion of others.
- All experiments to characterize the noise in pulsars are absolutely worth it. They have the potential to completely change the way we observe.
- Anisotropy of GW sources should be an ingredient in optimization schemes
- We should consider a targeted search for new pulsars toward Virgo/Coma/Fornax.