Timing Noise Analysis of NANOGrav pulsars

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PRESENTE
QUARTIERE CASTELLO

This slide contained a picture of Delphine's Drivers License and Italian Identity Card. For the sake of privacy they have been removed. Cheers! Imagine a funny drivers license picture.

Perrodin, Jenet, Lommen, Finn, Demorest, Ferdman, Gonzalez, Nice, Ransom, Stairs (2012)

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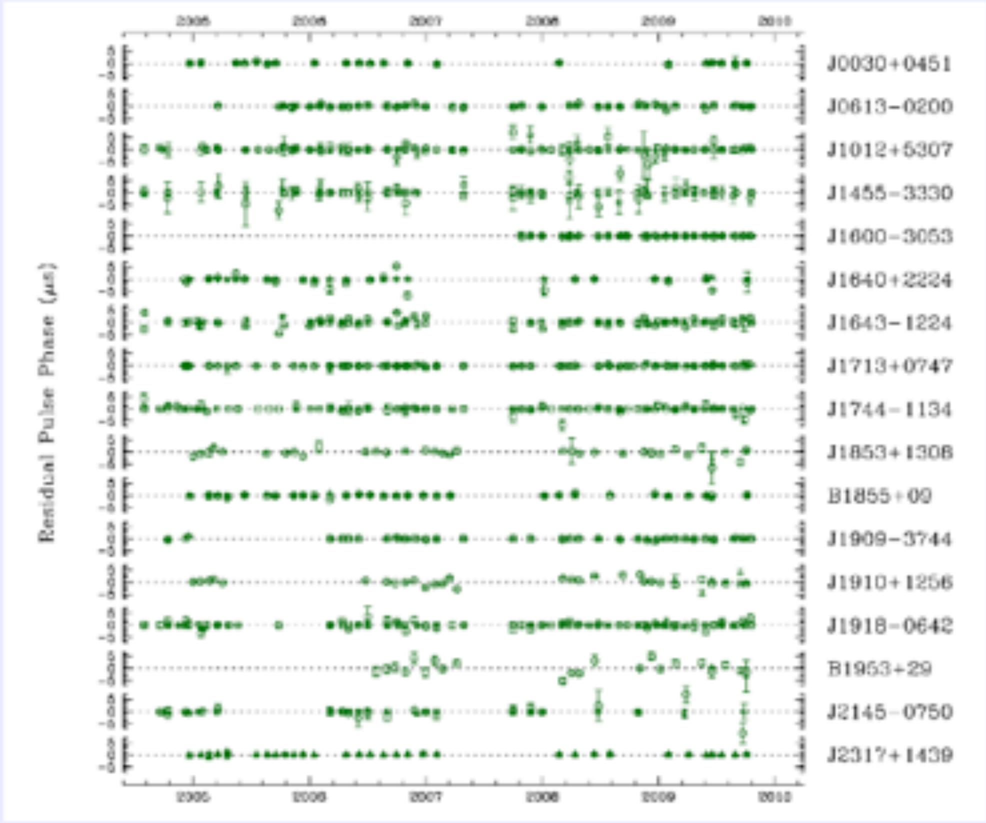
- Red noise in NANOGrav pulsars
- Observing strategies

NANOGrav residuals

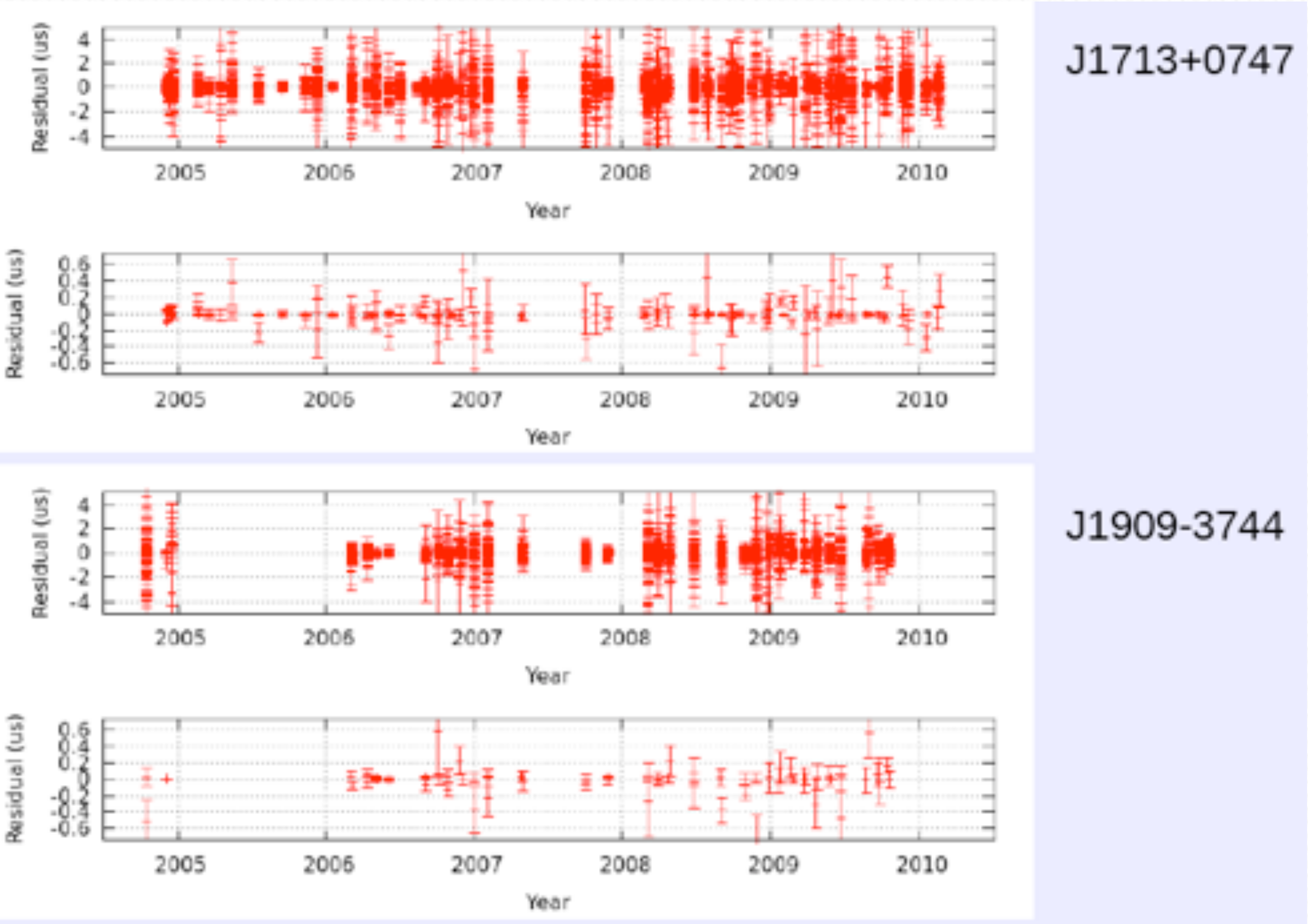
NANOGrav 5-year timing results overview:



(plot: D. Nice)

Demorest et al. (2012)

NANOGrav residuals



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- We calculated the autocorrelation function of timing residuals:

$$\hat{R}(k) = \frac{1}{(n-k)\sigma^2} \sum_{t=1}^{n-k} (X_t - \mu)(X_{t+k} - \mu)$$

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Did not find any non-white correlation with this method.

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Results? High X^2 in J1643-1224 (112), J1910+1256 (382) and J1640+2224 (654).

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$$C(d) = Ce^{-d/\tau} + \sqrt{2\pi}B\delta(d)$$

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Pulsar	Freq(MHz)	$C(10^{-13}s^2)$
J1910+1256	1400	9.9 ± 1.8
J2145-0750	1400	9.8 ± 1.3
J1643-1224	1400	11 ± 7

- Compare amplitude of non-white noise with amplitude of white noise
- Variance of white noise expected to decrease as 1/N

$$\sigma_w^2 = \frac{\sigma_0^2}{N}$$

- Improve rms until level of white noise down to level of red noise:

$$\sigma_w^2 = \frac{\sigma_0^2}{N} = \sigma_r^2$$

- Define:

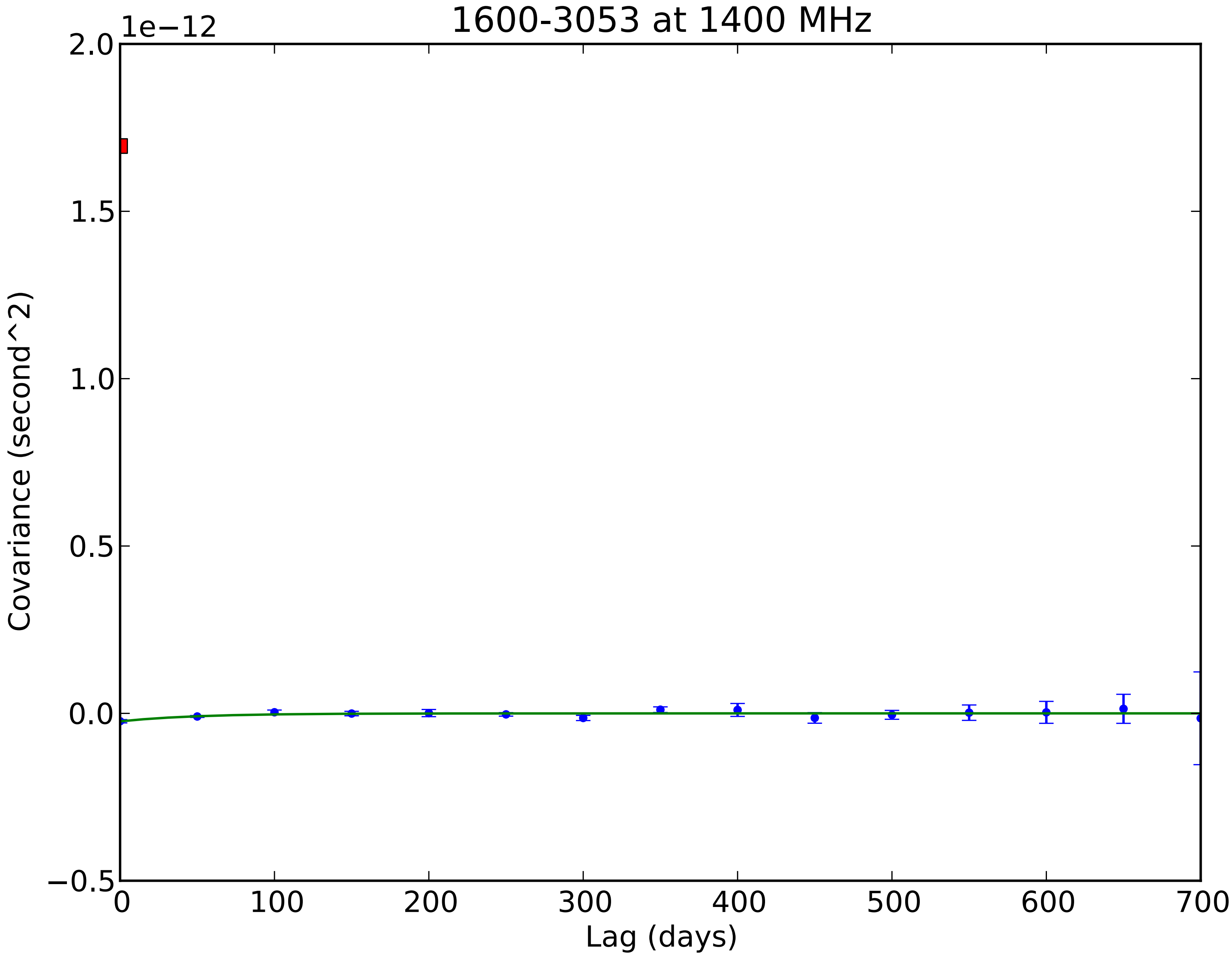
$$\text{Time Factor} = N = \frac{\sigma_0^2}{\sigma_r^2}$$

Can increase number of observations up to N times current number and still expect rms to go down as 1/sqrt(N)

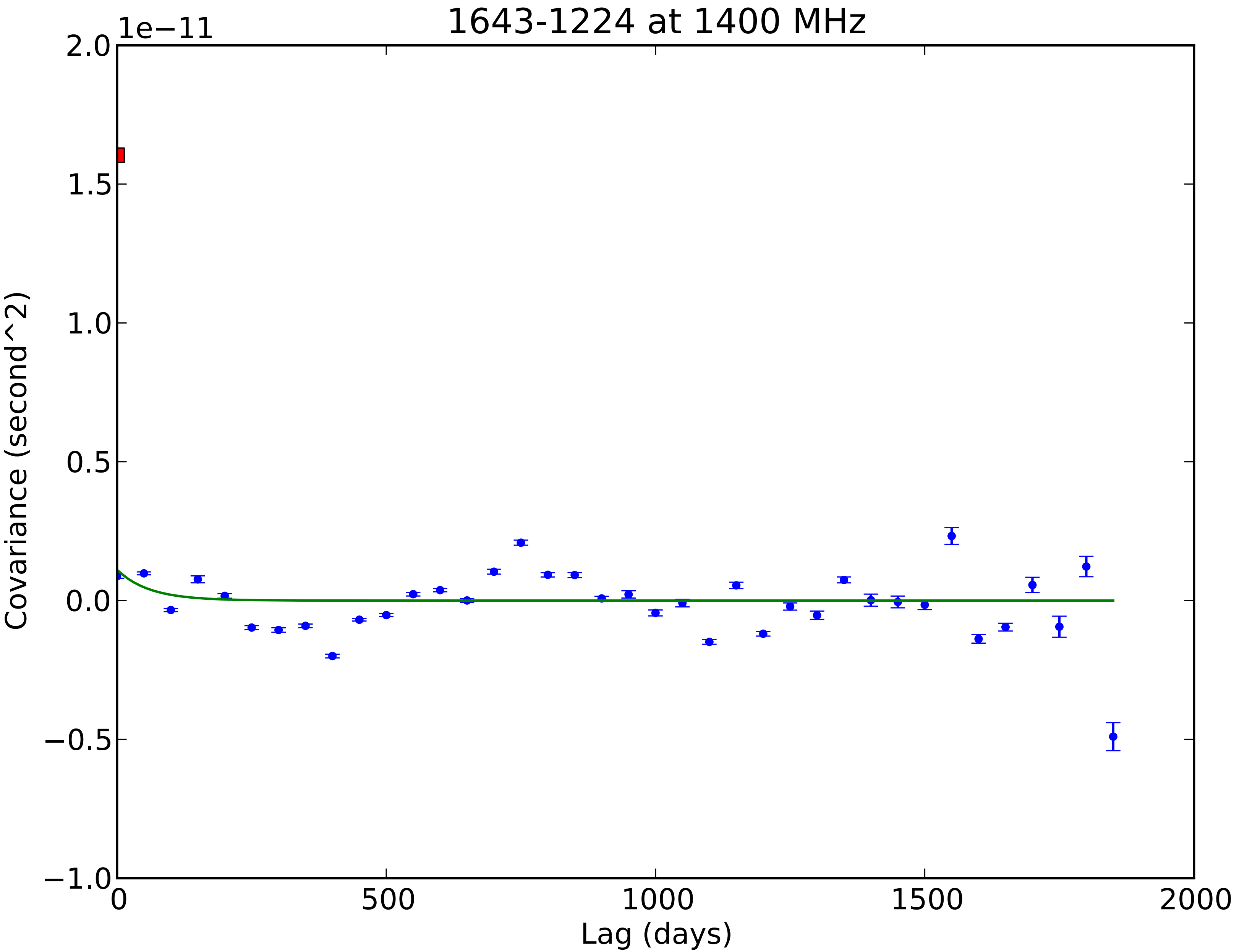
J1910+1256 and J1643-1224 exhibit the lowest factors:

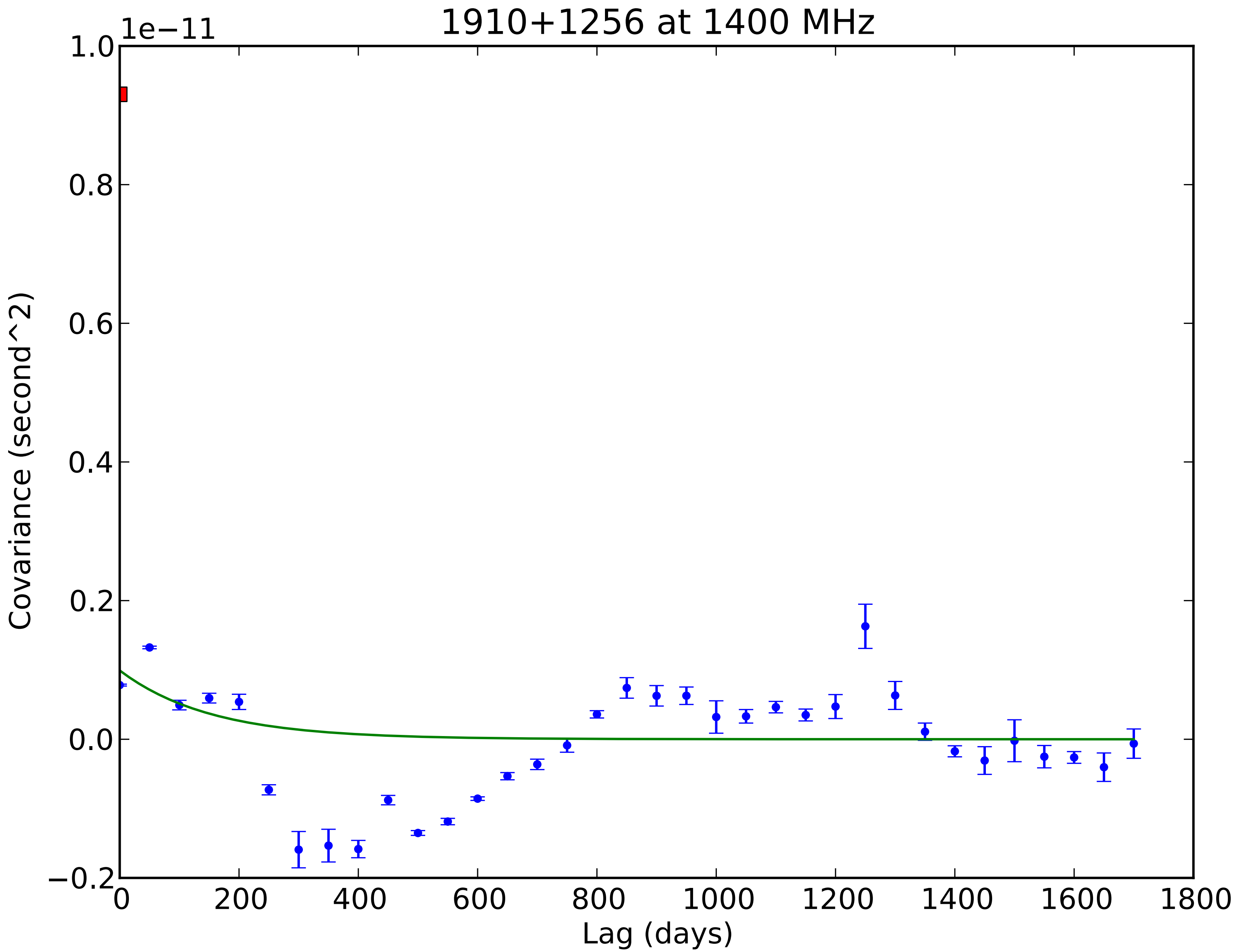
Pulsar	Freq(MHz)	Obs	χ^2	$C(10^{-13}s^2)$	Factor
J1910+1256	1400	AO	382	9.9 ± 1.8	7
J1643-1224	1400	GBT	112	11 ± 7	18
J1640+2224	1400	AO	654	–	40
J2145-0750	1400	GBT	37	9.8 ± 1.3	66

Even then, can increase the cadence or integration time 6-fold and still not reach the level of red noise -> incentive to increase observation time in order to achieve lower rms



1600-3053 at 1400 MHz
1e−12
2.0
1.5
1.0
0.5
0.0
−0.5
Covariance (second^2)
0
100
200
300
400
500
600
700
Lag (days)


1643-1224 at 1400 MHz
1e−11
Covariance (second^2)
Lag (days)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
0
500
1000
1500
2000



1910+1256 at 1400 MHz
1e−11
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
Covariance (second^2)
0
200
400
600
800
1000
1200
1400
1600
1800
Lag (days)

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- Try fitting more general functions?
- Bayesian methods are being explored (van Haasteren, Ellis)

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- However: J1910+1256 was only observed at one frequency and DM variations were not included -> not necessarily a "bad" pulsar
- J1640+2224 has orbital period close to ½ year, can lead to poor orbital sampling

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- Can freely increase the cadence or integration time of our observations in order to achieve lower rms and better sensitivity to GW
- DM variation method successful at removing red noise
- At IPTA level: should test DM variation algorithms on same data sets