Known Pulsar Search

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Nature of Gravitational Wave Signal

- The gravitational wave signal from a non-precessing pulsar can be modeled as

$$h(t) = F_+(t;\psi)h_0(1+\cos^2\iota)\cos 2\Psi(t) + 2F_\times(t;\psi)h_0\cos\iota\sin 2\Psi(t) \quad (1)$$

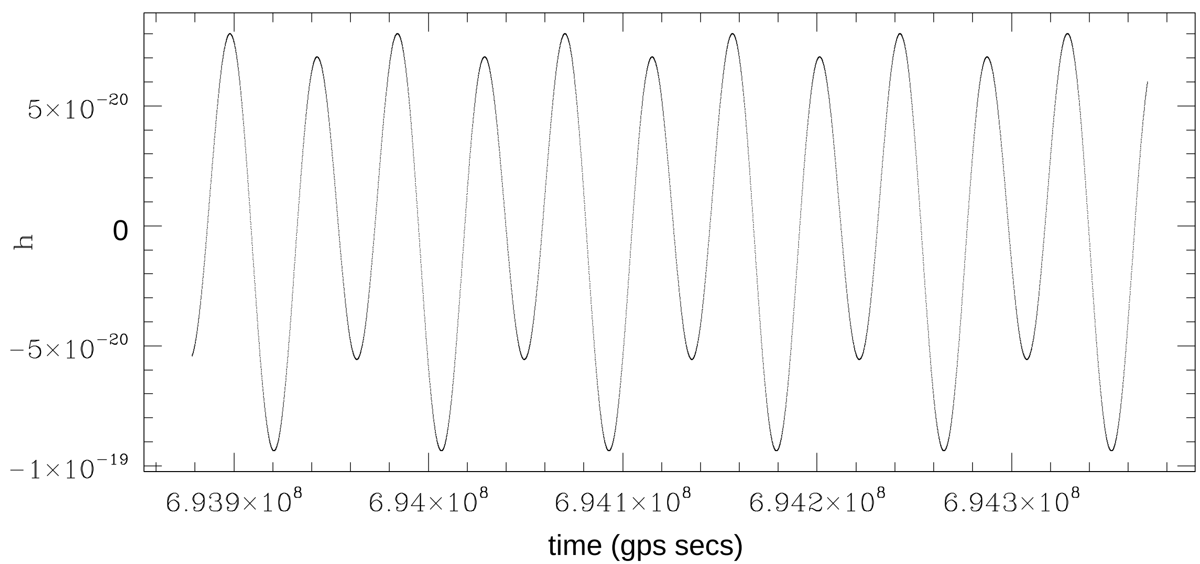
- Unknown parameters are
  - h_0 - amplitude of the gravitational wave signal
  - ι - angle between line of sight and ang. mom. vector
  - ψ - polarization angle of gravitational wave
  - ϕ_0 - initial phase of pulsar in $\Psi(t) = \phi_0 + \phi(t)$

Model Gravitational Wave Signal

The model gravitational wave signal after heterodyning at DC, including Doppler shift and spindown, is

$$y(t;\mathbf{a}) = F_+(t;\psi)h_0(1+\cos^2\iota)e^{i2\phi_0} - 2iF_\times(t;\psi)h_0\cos\iota e^{i2\phi_0} \tag{2}$$

- Tested against `LALSimulateTaylorCW()`



Least-Square Fitting

The reduced set of data points is then fitted to this model by minimizing χ^2 over h_0, ϕ_0, ι, and ψ.

$$\chi^2(\mathbf{a}) = \sum_k \left| \frac{B_k - y(t;\mathbf{a})}{\sigma_k^2} \right|^2 \qquad (3)$$

The time domain approach simplifies analysis of

- gaps
- non-stationarity

LAL Package: ***knownpulsartd***

Heterodyning

`LALCoarseHeterodyne()`

- heterodyne fixed frequency
- low-pass, avg, and decimate
- output diagnostics of noise

→

`LALFineHeterodyneToPulsar()`

- Doppler and spindown
- low-pass, avg, and decimate
- variance for each point

Fitting

`LALCoarseFitToPulsar()`

- fit using fixed grid
- solve directly for min h_0
- standard error of parameters

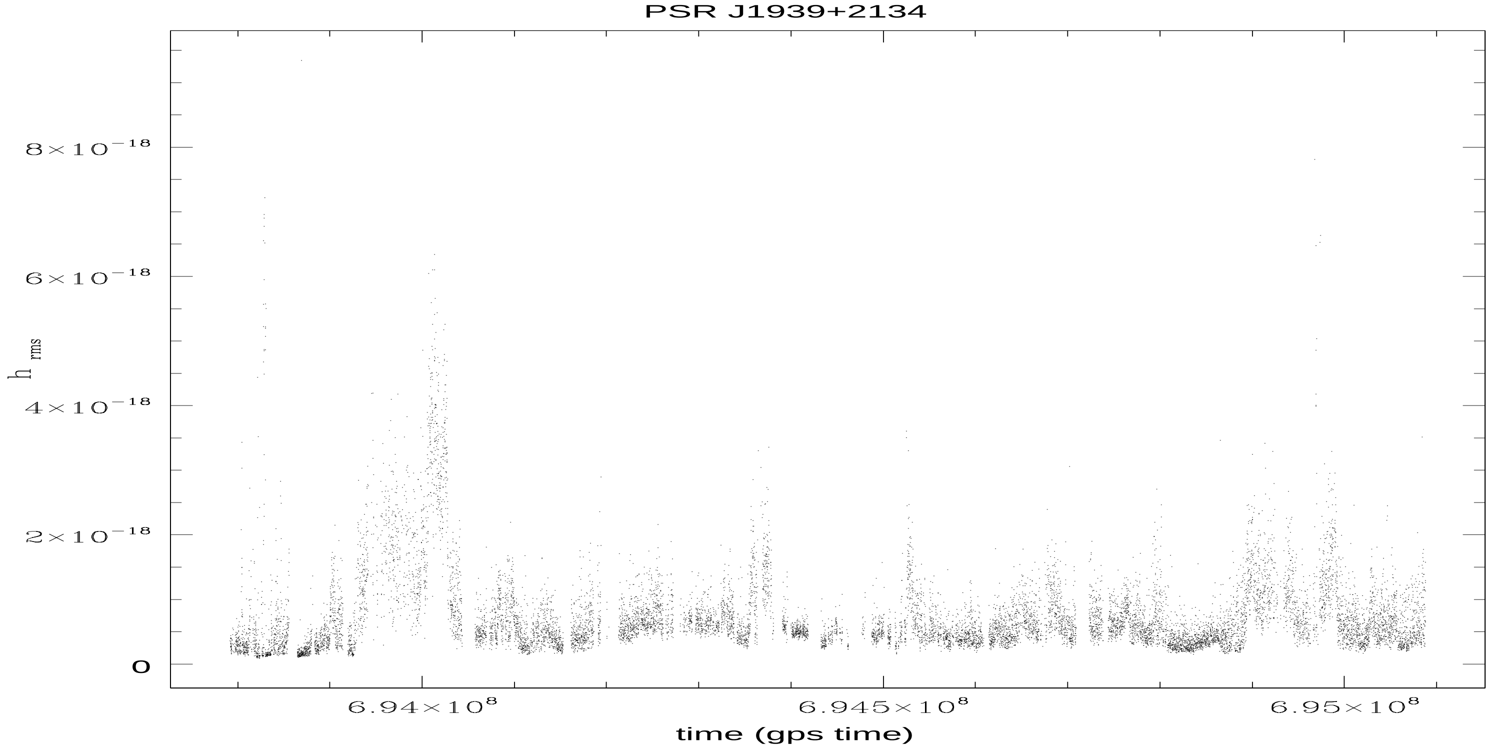
→

`LALFineFitToPulsar()`

- Levenberg-Marquardt method
- Calculate Hessian of χ^2
- Estimate standard errors

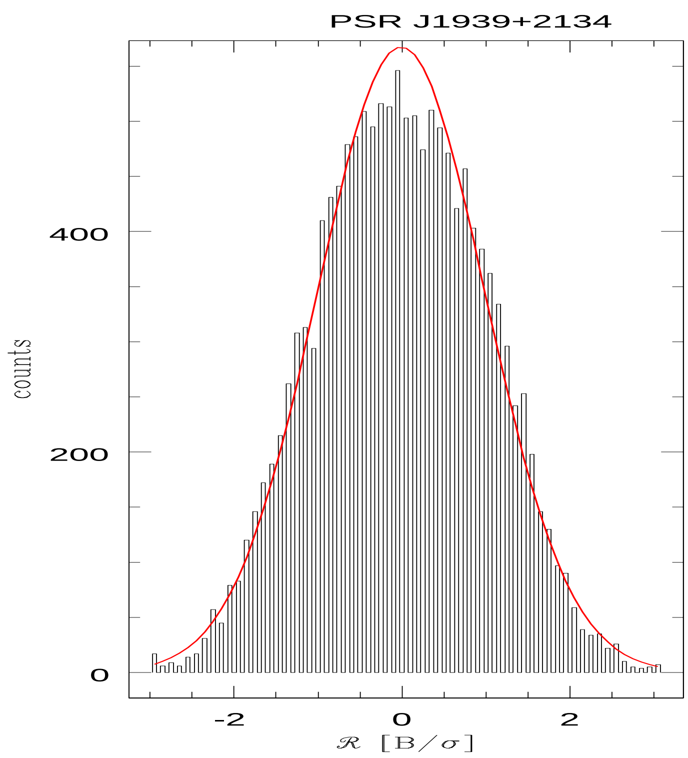
Preliminary Analysis

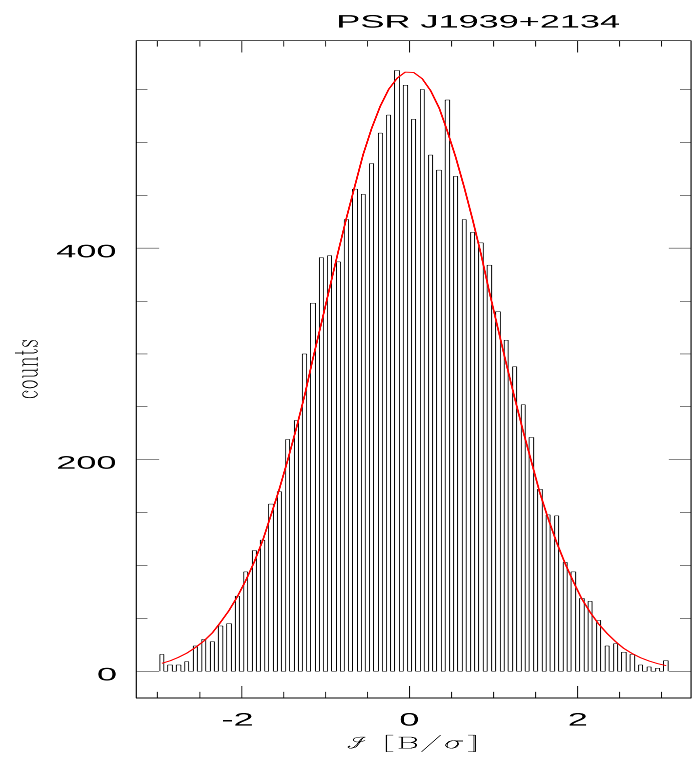
- 15 days of GEO data from coincidence run
- Only used data with lock stretches > 3 min
- This gives an overall duty cycle of 65.9% (vs 72.0%)



Preliminary Analysis

- B/σ is good fit to Gaussian
- χ^2 appropriate statistical test





Preliminary Upper limit for J1939+2134

- Simple calcs from spectrum $\sigma_{h_0} \approx 5.78 \times 10^{-21}$

$$\sigma_{h_0} = \frac{h_{\rm rms}}{\sqrt{N}} \tag{4}$$

- Ignoring beam pattern $\sigma_{h_0} \approx 2.96 \times 10^{-21}$

$$\sigma_{h_0} = \frac{1}{\sum 1/\sigma_i} \tag{5}$$

- Unmarginalized min and max standard error $\sigma_{h_0} \approx 2.31 \times 10^{-21} \rightarrow 7.76 \times 10^{-21}$

$$\sigma_{h_0} = \left(\frac{1}{2} \frac{\partial^2 \chi^2}{\partial h_0^2} \right)^{-\frac{1}{2}} \tag{6}$$

Plans

- Further Monte Carlo tests of performance, robustness, and efficiency
- Marginalize upper limits on h_0
- Exercise the software on other pulsars
- Extend to include precessing pulsars (eg SN1987A ?)
- Extend to binary systems