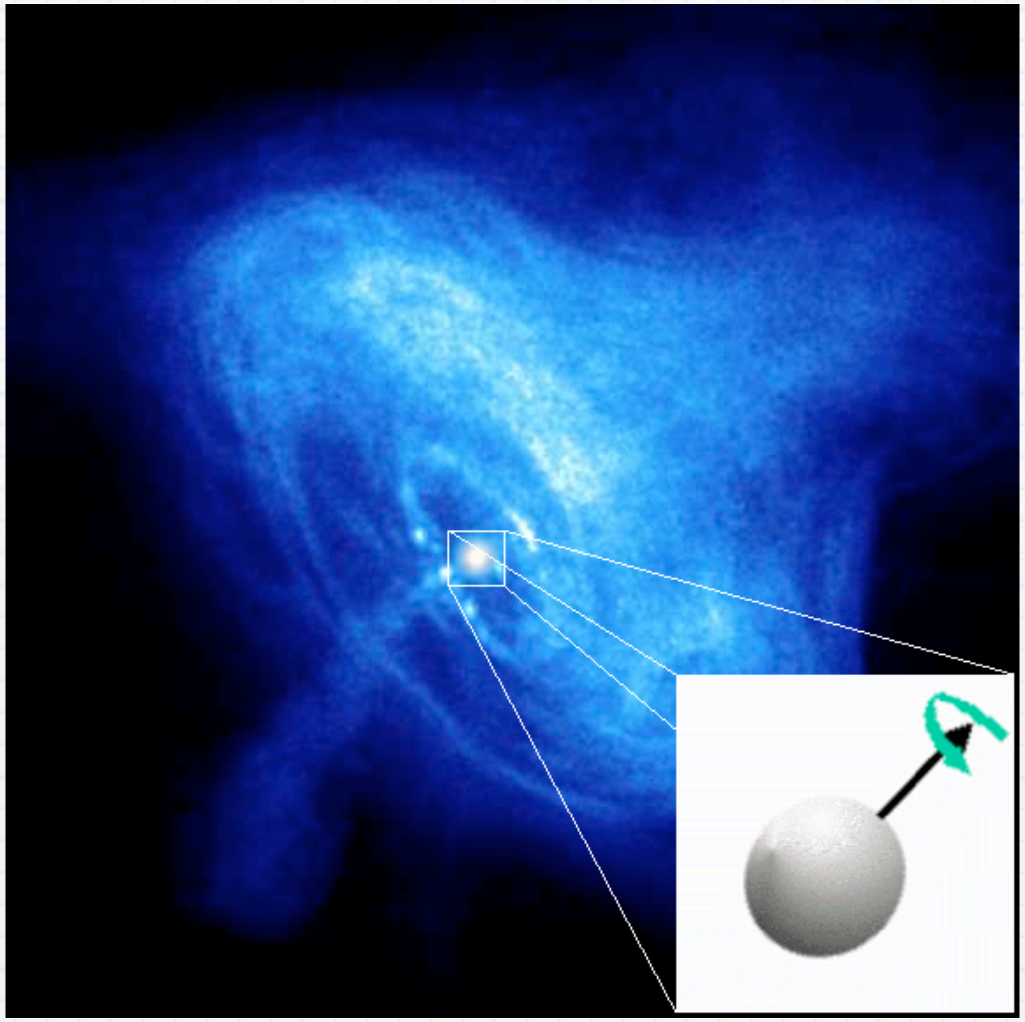
Searching for “transient” GWs from NSs



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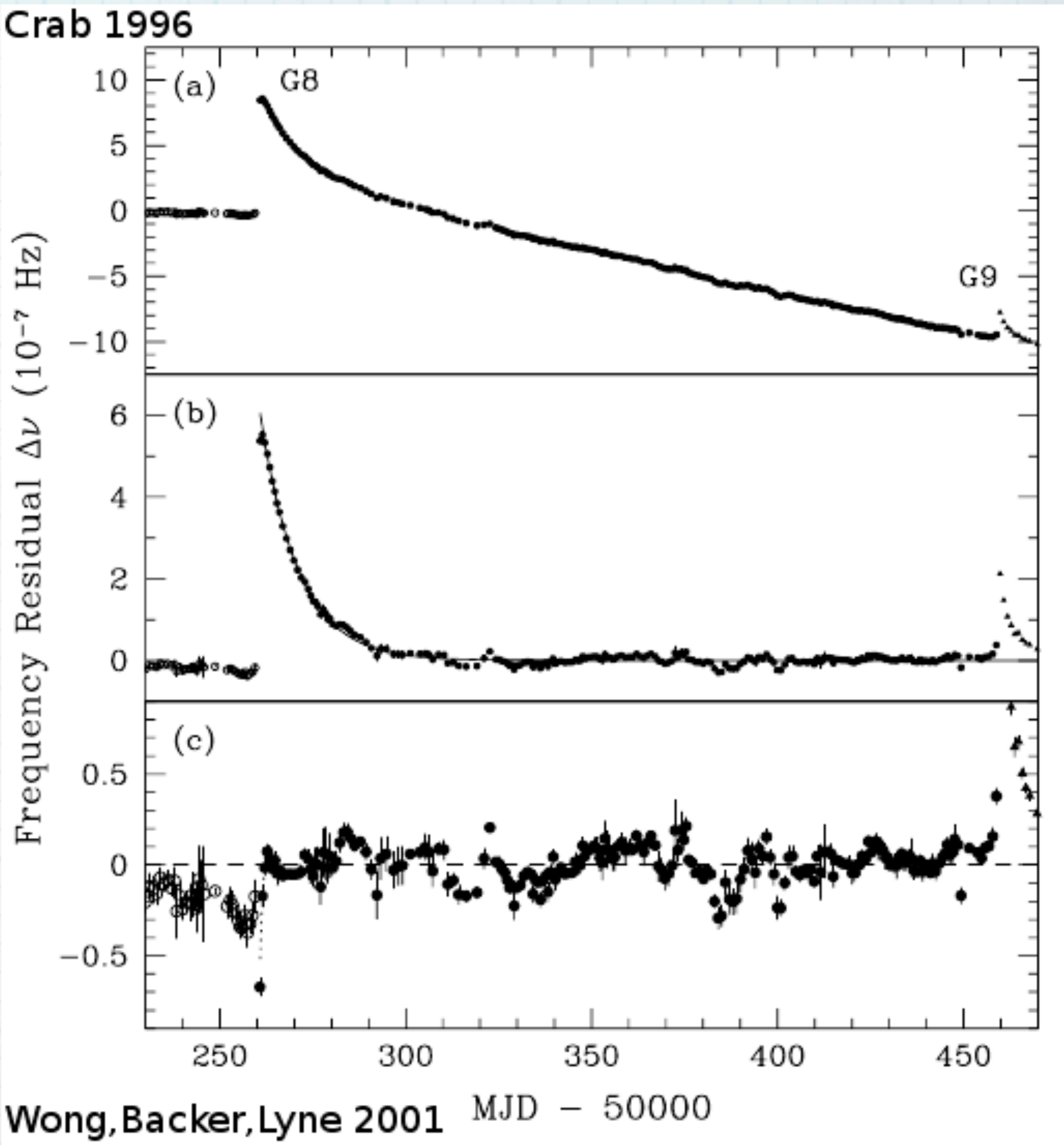
Searching for “transient” GWs from NSs

* What do we mean by “transient GWs”?
* Motivation for this search.
* Search method.
* Parameter space and computational cost.
* Detection statistic.

Motivation for this search

- No specific mechanisms predicting such signals!
- Our NS-physics understanding is vague though.
- Unexplained glitches in NSs rotation rates are observed.
- Strong GWs, likely to be related to transient events in NSs ?
- Cover intermediate time scale between "bursts" and "CWs".



Math

* **Model:** $$h_+(\tau) = A_+ \cos\Phi(\tau)\, g(\tau)\,, \quad h_\times(\tau) = A_\times \sin\Phi(\tau)\, g(\tau)$$
* **phase evolution** $$\Phi(\tau) = \phi_0 + \phi(\Delta\tau)$$ $$\phi(\Delta\tau) = 2\pi \sum_{s=0} \frac{f^{(s)}}{(s+1)!} [\Delta\tau]^{s+1}$$
* **Signal:** $$h(t) = \sum_{\mu=1}^{4} \mathcal{A}^\mu h_\mu(t)$$ JKS 1998
* **Parameters:**

$$\begin{aligned}
\mathcal{A}^1 &= A_+ \cos\phi_0 \cos 2\psi - A_\times \sin\phi_0 \sin 2\psi\,,\\
\mathcal{A}^2 &= A_+ \cos\phi_0 \sin 2\psi + A_\times \sin\phi_0 \cos 2\psi\,,\\
\mathcal{A}^3 &= -A_+ \sin\phi_0 \cos 2\psi - A_\times \cos\phi_0 \sin 2\psi\\
\mathcal{A}^4 &= -A_+ \sin\phi_0 \sin 2\psi + A_\times \cos\phi_0 \cos 2\psi
\end{aligned}$$

$$\begin{aligned}
h_1(t) &= a(t) \cos\phi(\Delta\tau)\, g(t)\,, \quad h_2(t) = b(t) \cos\phi(\Delta\tau)\, g(t)\\
h_3(t) &= a(t) \sin\phi(\Delta\tau)\, g(t)\,, \quad h_4(t) = b(t) \sin\phi(\Delta\tau)\, g(t)
\end{aligned}$$

Search method

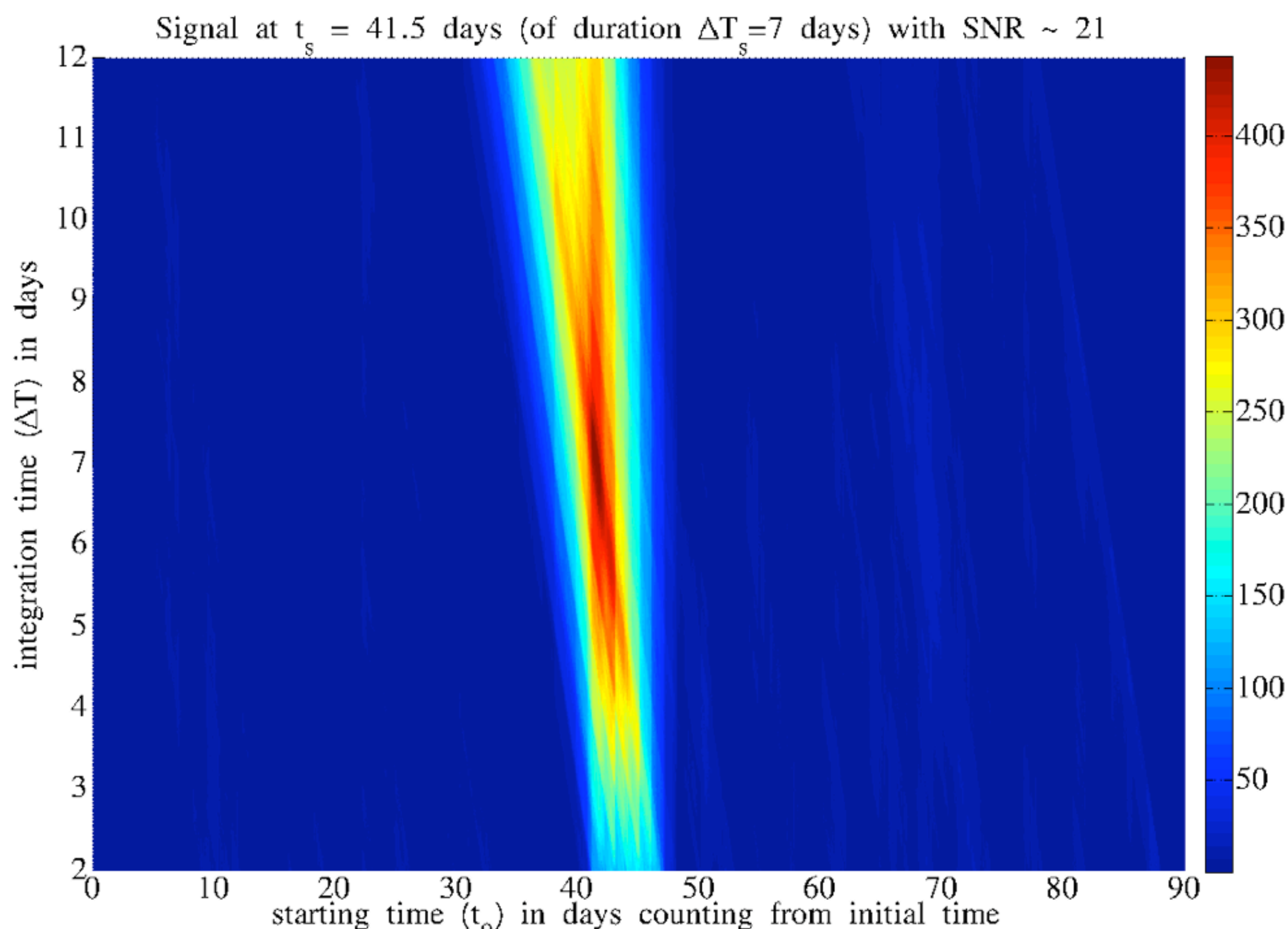
* Use F-Statistic (maximum likelihood) and Bayesian inference.

* Marginalize over extra parameters (t_0, ΔT) and compute a "statistic".

* Assign statistical significance to possible candidate signals.

Example

* Simulated signal into Gaussian noise



Computational cost

* The 2 additional parameters DO NOT greatly affect the cost of the search ("targeted searches")!

* The number of floating point operations needed in post-processing {A, B, C, Fa, Fb} (computed every ~10^3 sec), for a given Doppler parameter template, over 1 year of data, with time window of up to 2 weeks, is ~ 10^7.

Statistics - Hypothesis testing

* 2 hypotheses:

  - null hypothesis
  - signal case

$$\mathcal{H}_0 : \boldsymbol{x}(t) = \boldsymbol{n}(t)$$
$$\mathcal{H}_1 : \boldsymbol{x}(t) = \boldsymbol{n}(t) + \boldsymbol{s}(t; \mathcal{A}, \lambda, t_0, \Delta T)$$

$$\boldsymbol{s}(t; \mathcal{A}, \lambda, t_0, \Delta T) = \mathcal{A}^\mu \, \boldsymbol{h}_\mu(t; \lambda) = \begin{cases} \boldsymbol{s}(t; \mathcal{A}, \lambda), & t \in [t_0, t_0 + \Delta T] \\ 0, & \text{otherwise} \end{cases}$$

* Testing:

  - Odds ratio

$$O_{10}(x|I) = \frac{P(\mathcal{H}_1|xI)}{P(\mathcal{H}_0|xI)} = \frac{pdf(x|\mathcal{H}_1 I)}{pdf(x|\mathcal{H}_0 I)} \frac{P(\mathcal{H}_1|I)}{P(\mathcal{H}_0|I)}$$

  - Bayes factor

$$\mathcal{B}_{10} \propto \int e^{\mathcal{F}(x, \lambda, t_0, \Delta T)} P(t_0, \Delta T | \mathcal{H}_1) dt_0 \, d\Delta T$$

Future plans

* Learn more about NSs.

* Derive an exact expression for the odds ratio.

* Perform more simulations/tests.

* Apply method on real data, doing:

  - "targeted" searches

  - "directed" searches