LIGO-G070353-00-Z

Einstein@Home Hierarchical Search

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What is Einstein@Home?

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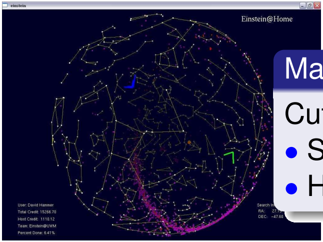
Search for GWs from spinning neutron stars with unknown sky-position, frequency & spindown: $\lambda = \{\alpha, \delta, f, \dot{f}\}$



Maximize available computing power

Cut parameter-space λ in small pieces $\Delta\lambda$

- Send workunits $\Delta\lambda$ to participating hosts
- Hosts return finished work and request next

- Public distributed computing project, launched Feb. 2005
- Currently $\sim$160,000 active participants, $\sim$80Tflops
- runs on GNU/Linux, Mac OSX, Windows,..
- Search for isolated neutron stars $f \in [50, 1500]\,\mathrm{Hz}$
- Aiming for detection, not upper limits
- Analyzed data from S3, S4, currently S5

Status of previous searches

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- S3 analysis
  - Analysis and post-processing complete
  - Results reviewed and approved
  - Final report posted on E@H website
- S4 analysis [S4 R2]
  - Analysis and post-processing complete
  - Soon to be reviewed
- First S5 analysis [S5 R1]
  - Analysis complete
  - Post-processing will be similar to S4 R2
- Hierarchical S5 analysis [S5 R2]
  - Started test-run ($\sim$ 3 months)
    ☞ currently working on improving stability & reliability
  - Will be followed by a full 1-year run

Hierarchical Search [S5 R2]: Motivation

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- Previous analyses return results of a coherent search from different data segments ("stacks")
- Stack-coincidence analysis performed in post-processing
- Sensitivity limited by high effective threshold on stacks (limited by returnable data volume)

☞ We should do the "coincidence" on the host machines!

Hierarchical search developed by a number of CW members

(B. Allen, T. Creighton, D. Hammer, B. Krishnan,
B. Machenschalk, G. Mendell, B. Owen, M.A. Papa, R. Prix,
X. Siemens, A. Sintes, ...)

Hierarchical Search: Basic algorithm

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- Split observation time into $N_{\rm stack}$ “stacks” of duration $T_{\rm stack}$
- For each sky-position (α, δ) and spindown value $(\dot{f})$: compute $\mathcal{F}$-statistic for each stack over frequency band Δf
- Combine $\mathcal{F}(f)$ from the stacks using Hough (or StackSlide)
- Use stack-weighting according to noise and beam pattern
- Select candidates from the semi-coherent step
- Return a toplist of $N_{\rm max}$ most significant candidates (currently $N_{\rm max} = 10,000$)

Sensitivity estimate of different E@H Runs

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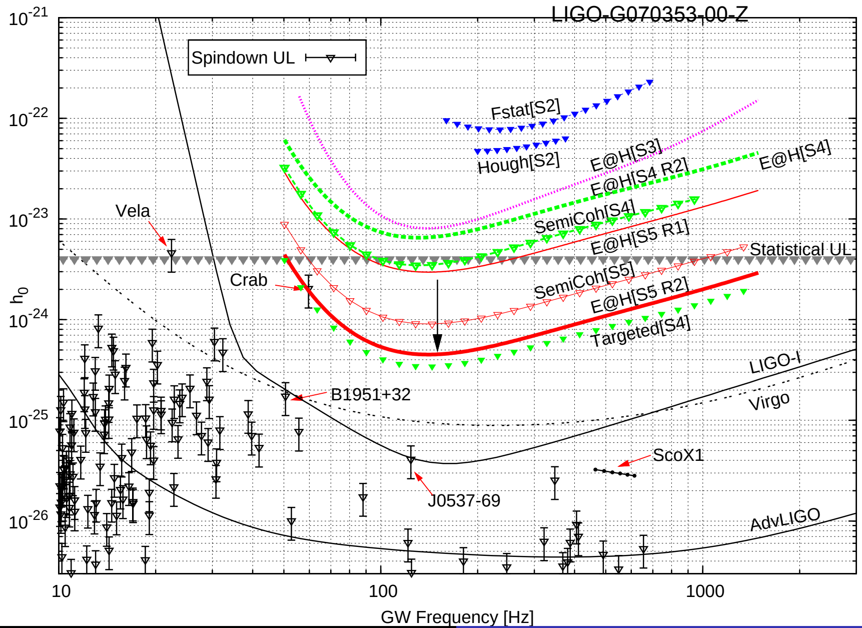
Stage 1: $\mathcal{F}$-statistic on N_{stack} stacks of T_{stack}
Stage 2: coincidence or Hough/StackSlide on stacks
(Stage 3: follow-up or upper-limit)

☞ Sensitivity estimate ($\text{fA} = 3 \times 10^{-13}$, $\text{fD} = 10\,\%$, $\text{MM} = 0.5$):

$$\langle h_0 \rangle_{\text{fA}}^{\text{fD}} \sim \frac{5/2}{\sqrt{\text{MM}}} \frac{\text{SNR}_1(\text{fA}, \text{fD}, \mathcal{F}_{\text{th}})}{N_{\text{stack}}^{1/4} \sqrt{N_{\text{det}}\, T_{\text{stack}}}} \sqrt{S_n} \equiv \frac{\sqrt{S_n \cdot \text{Hz}}}{\text{sens}}$$

RUN	N_{stack}	T_{stack}	N_{det}	$2\mathcal{F}_{\text{th}}$	on-host	post-P	sens	$\frac{\langle h_0 \rangle_{\text{best}}}{10^{-24}}$
S3 R2	60	10 h	1	25	2-coinc	coinc	7.3	8
S4 R2	17	30 h	1	26*	—	coinc	8.4	6
S5 R1	28	30 h	1	26*	—	coinc	9.6	3
S5 R2	84	25 h	2	**5.2**	Hough	—	63	0.45

The Big Picture



The semi-coherent step

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- For a signal mismatched with the demodulation point, the local maximum will lie on a circle in the sky
- The circle in stack *i* is determined by the master-equation

$$f - f_0 = f_0 \frac{\mathbf{V}_i}{c} \cdot (\mathbf{n}_0 - \mathbf{n})$$

- The circles have different orientation for different stacks – this leads to a refinement in the parameter space from using a semicoherent method