The Einstein@Home search for periodic gravitational waves in LIGO S4 data

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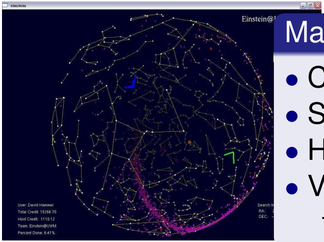
Einstein@Home S4 Search: Executive summary

- Blind all-sky broad-band search for periodic gravitational waves from isolated neutron stars
- Used 510 hours of data from the S4 LIGO Science run: 10 segments of 30h duration from H1 and 7 from L1.
- Searched frequency range $50\,\mathrm{Hz} \le f \le 1\,500\,\mathrm{Hz}$
- Searched spin-down range $-f/\tau \le \dot{f} \le 0.1 f/\tau$ with $\tau = 1\,000\,\mathrm{years}$ below $f = 300\,\mathrm{Hz}$ and $\tau = 10\,000\,\mathrm{years}$ above $300\,\mathrm{Hz}$.
- **Huge** parameter-space search was distributed over $\sim 100\,000$ computers volunteered by the general public
- More than 90% of sources with dimensionless gravitational wave strain amplitude greater than 10^{-23} would have been detected in the most sensitive band $100\,\mathrm{Hz}$ - $200\,\mathrm{Hz}$.
- No gravitational-wave signals were detected
- Full paper: **http://arxiv.org/abs/0804.1747**

Search method

- Goal: high-confidence **detection** (not upper limits)
- Grid 4-d parameter space $(f, \dot{f}, \alpha, \delta)$. Points spaced at equal SNR loss.
- Find optimal "2F" statistic (SNR) at each point with linear coherent filter of 30 hours.
- Total number of templates (parameter space points examined): 63 627 287 767 483.
- Kept most significant events in each narrow frequency band: floating threshold $2F$ between 26 and 28.
- Detection: an event appearing above threshold in the same part of the parameter space in at least 12 of the 17 different 30h data segments.
- Sensitivity assessed with Monte-Carlo simulations.
- Pipeline also validated with ten hardware injections.

What is Einstein@Home?



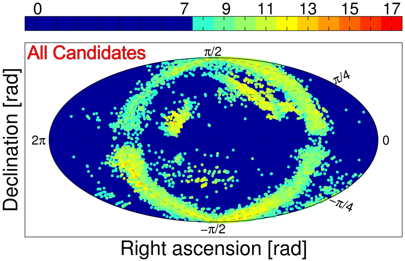
Maximize available computing power

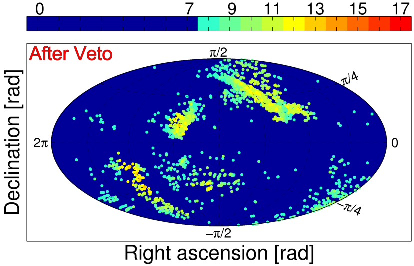
- Cut huge parameter space in small *workunits*
- Send these workunits to participating hosts
- Hosts return finished work and request more
- Validation: all work done by multiple users then automatically compared.

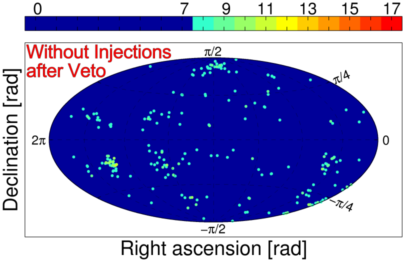
- Public distributed computing project, launched in February 2005
- Uses BOINC (Berkeley Open Infrastructure for Network Computing)
- Runs under Windows, Mac OS X, Linux, FreeBSD, Solaris
- Community features: teams, message boards, user profiles
- Currently $\sim$100 000 active participants, $\sim$100Tflops

Final results from S4 Search

Skymaps of coincident candidate events among 17 segments:







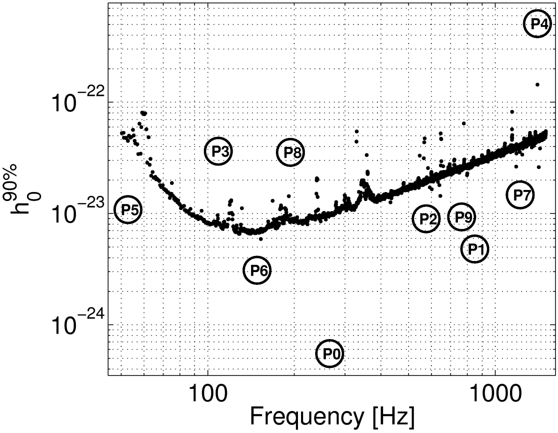
After excluding hardware-injected pulsar signals and candidates consistent with stationary instrumental lines (S-veto), no detection candidates (*coincidences* $\geq$ 12) remain.

Estimated Sensitivity of S4 Search

At what gravitational wave strain amplitude h_0 would 90% of sources give 12 or more coincidences among the 17 segments?

$$h_0^{90\%} \sim 32 \sqrt{\frac{S_h(f)}{30\,\text{hours}}}$$

Determined by Monte-Carlo simulation for sources uniformly distributed over the sky, with uniform distributions of the nuisance parameters.



Future Plans

- Einstein@Home is now searching the LIGO S5 data set
- New search method and better data should increase strain sensitivity by factor ≈ 5.
- Einstein@Home will be the LIGO Scientific Collaboration's main deep wide-band all-sky CW search
- Those of you who run Einstein@Home: THANK YOU
- Everyone else, please help us find gravitational waves! You can sign up for Einstein@Home at `http://einstein.phys.uwm.edu/`.