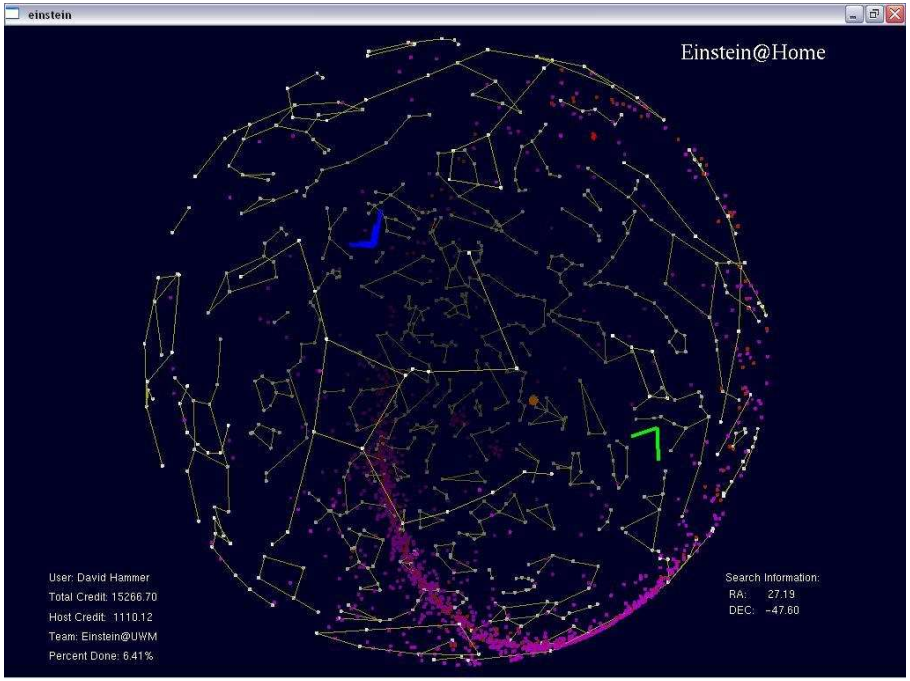
Einstein@Home: results and status

http://einstein.phys.uwm.edu

APS meeting, Dallas, April 2006



Reinhard Prix (Albert-Einstein-Institut)

for the LIGO Scientific Collaboration

Einstein@Home goals

- Matched-filtering ("$\mathcal{F}$-statistic") search for continuous GWs, e.g. from spinning neutron stars:
  ☞ *optimal sensitivity*
- Wide parameter-space search (all-sky, "all-frequency")
  ☞ computationally *limited* (SNR $\propto \sqrt{T}, N_p \propto T^5$)
- Aiming at *detection*, not upper limits
- Public outreach (WYP2005), distributed computing (2nd biggest distributed project after SETI@Home)

Einstein@Home - Server Status

Einstein@Home server status as of 5:31 PM UTC on Saturday, 25 March 2006 (updated every 20 minutes).
The Einstein@Home main server has been continuously up for 35 days 15 hours 1 minutes.

Server status

Program	Host	Status
Web server	einstein	Running
Albert work generator	einstein	Running
BOINC database feeder	einstein	Running
BOINC transitioner	einstein	Running
BOINC scheduler	einstein	Running
Albert validator	einstein	Running
Albert assimilator	einstein	Running
BOINC file deleter	einstein	Running
BOINC database purger	einstein	Running

Download mirror status

Site	Status	Last failure
Albert Einstein Institute	Running	623 h 15 m ago
University of Glasgow LSC group	Running	915 h 1 m ago
MIT LSC group	Running	915 h 1 m ago
Penn State LSC group	Running	272 h 43 m ago

Improved S4 search progress

Total needed	Already done	Work still remaining
6,731,410 units	3,014,419 units	3,716,991 units
100 %	44.781 %	55.219 %
204.8 days	91.7 days	113.1 days (estimated)

Users and Computers

USERS	Approximate #
in database	182,500
with credit	111,668
registered in past 24 hours	291

HOST COMPUTERS	Approximate #
in database	341,005
registered in past 24 hours	931
with credit	211,420
active in past 7 days	74,661
potential floating point speed[1)]	93.4 TFLOPS
floating point speed[2)]	41.5 TFLOPS

Work and Results

WORKUNITS	Approximate #
in database	429,482
with canonical result	266,993

RESULTS	Approximate #
in database	1,348,546
unsent	26,875
in progress	218,782
deleted	821,752
valid	801,550
valid last week	607,354
invalid	414
Oldest Unsent Result	6 d 22 h 37 m

1) the sum of the benchmarked FLops/s of all hosts that have contacted the Einstein@Home scheduler within the past week
2) from the sum of the Recent Average Credit (RAC) for all users

Return to Einstein@Home main page

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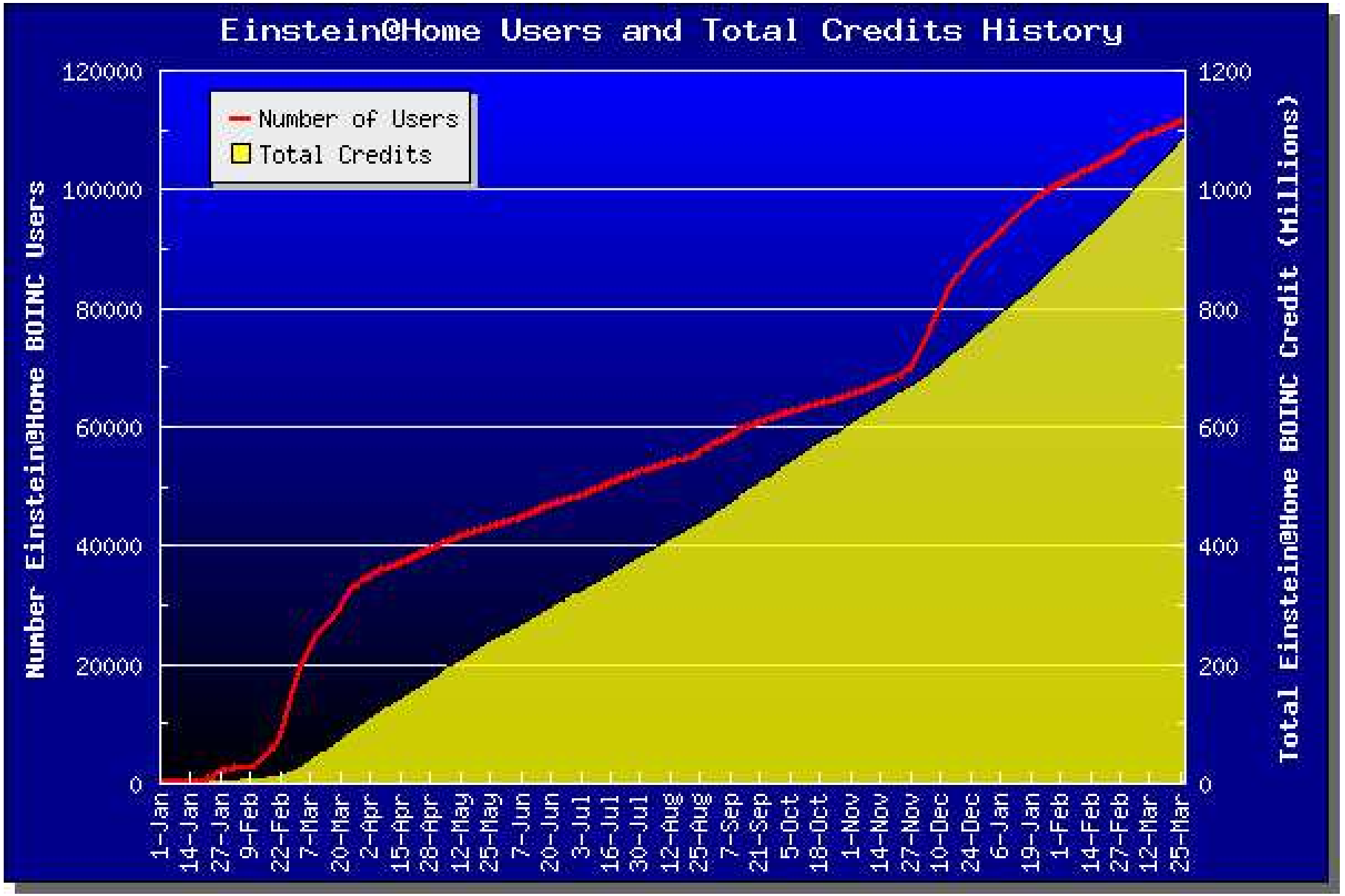
E@H timeline

- Nov 2004: unofficial test-launch
- 19 Feb 2005: official public launch, analyzing S3 data H1, T=10 h segments (application 'einstein')
- 3 May 2005: started second S3 search: using final calibration, line-cleaning, software injections
- 27 June 2005: started search on S4 data (H1 + L1)
- Sept 2005: partial S3 results on E@H web-pages
- Dec 24 2005: started *improved* S4 search.
  ☞ Optimized sensitivity for E@H (T=30 h).
  Application 'albert'. Run-time: ∼6 months.

E@H growth



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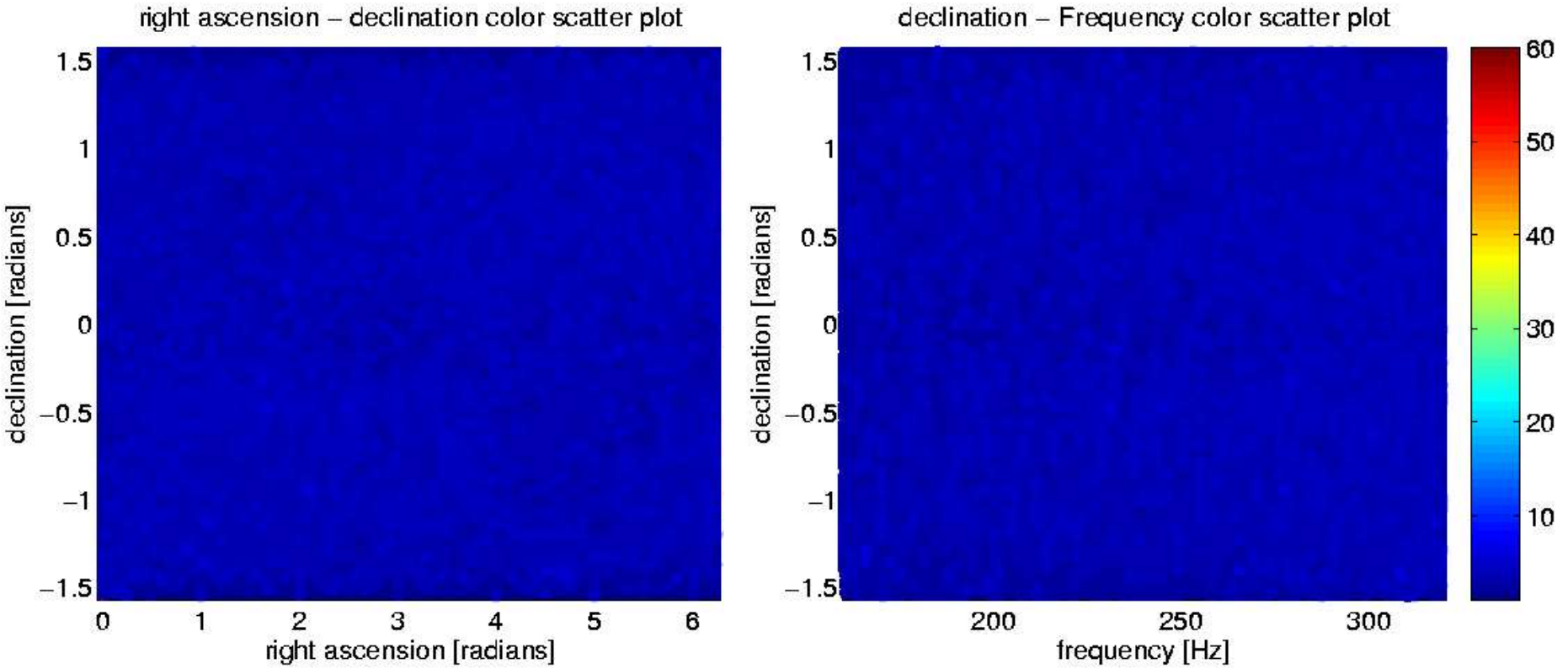
S3 search: pipeline

- Each host analyzes *two* T=10-hour segments:
  - *isotropic* sky-grid ($\sim 3 \times 10^4$ points), 0.1 Hz band
  - keep candidates $(f, \alpha, \delta, \mathcal{F})$ with $2\mathcal{F} > 25$
  - require *coincidence* between the two segments within $\Delta f \leq 10^{-3}$ Hz and angle $\Delta\Omega \leq 0.02$ rad
  - return surviving candidates to the server
- Total number of workunits $\sim 4 \times 10^5$
- Each workunit done by at least *three different users*, and is validated by comparison
- *Offline post-processing*: count number N of coincidences between *all 60* time-segments ($N \leq 60$)

S3 search: the data

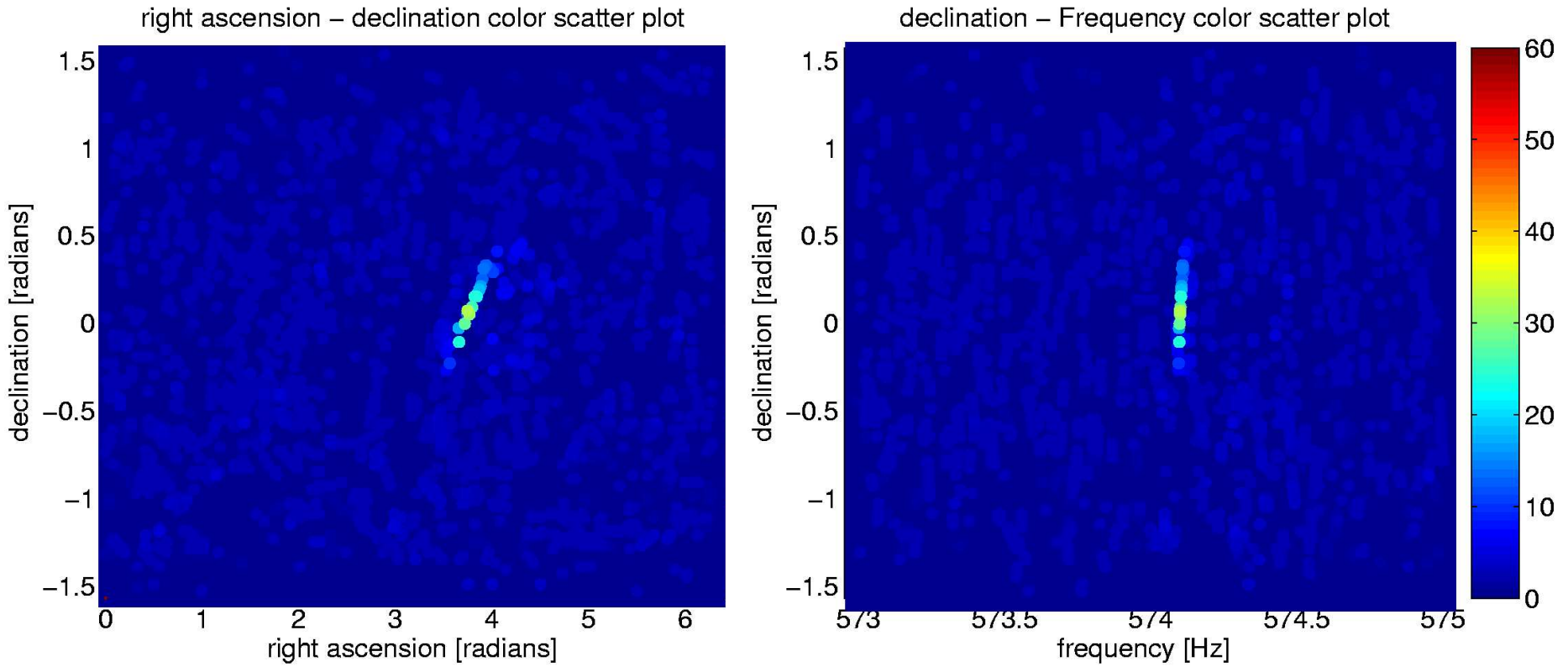
- most sensitive 600 hours of *S3* data from H1
  Frequency-range: $f \in [50, 1500]$ Hz
- $h(t)$ data, band-passed, windowed, 30 min FFTs
- *cleaned* all known "lines" (reduce false alarms)
- each hosts gets 0.5 Hz band with all 60$\times$10-hour data-segments ($\sim$ 14 MB): ☞ many workunits
- Total data-set: 2901 data-files of 0.5Hz

S3 results: clean band



Clean band, no visible sources.
Expected coincidences in Gaussian noise: $\langle N \rangle \sim 6$.

S3 results: injected pulsar

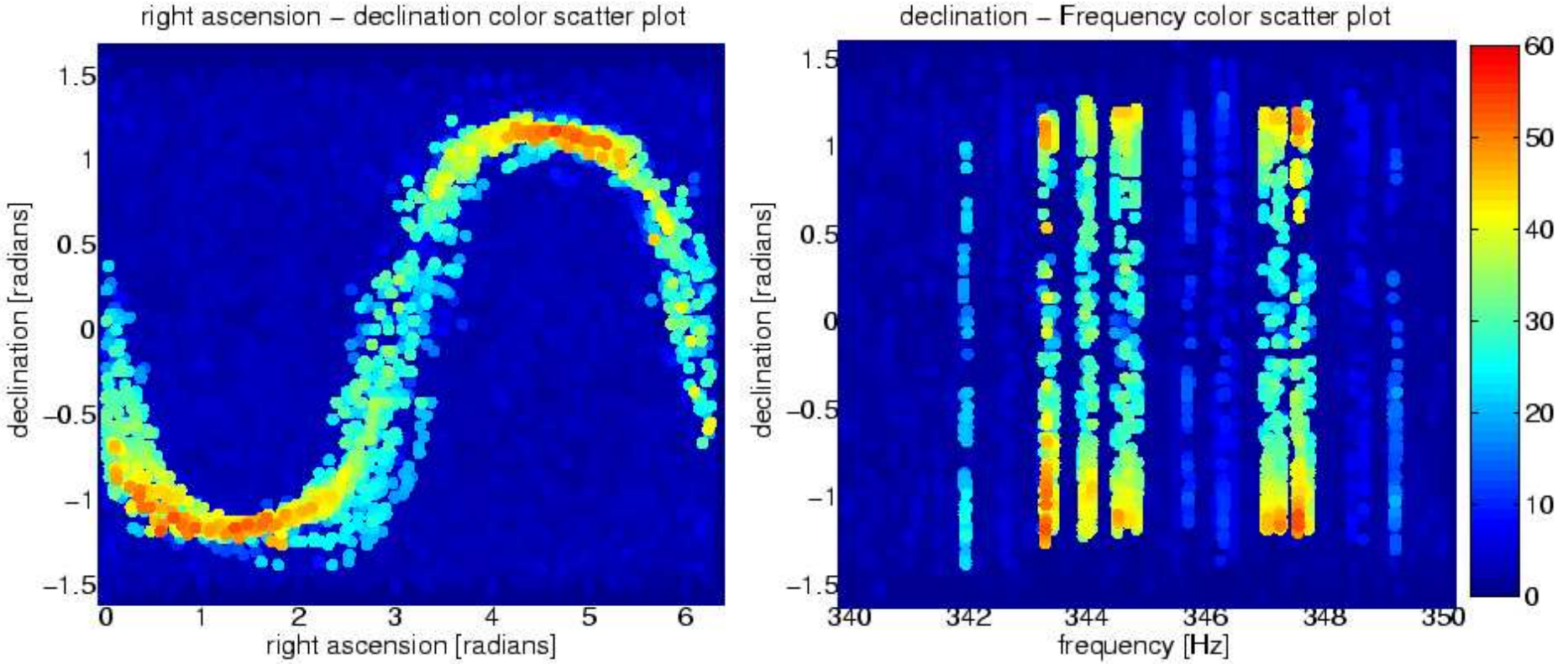


Software-injected pulsar:

$h_0 = 1.5 \times 10^{-23}$, $f = 574.1$ Hz, $\alpha = 3.8$, $\delta = 0.06$

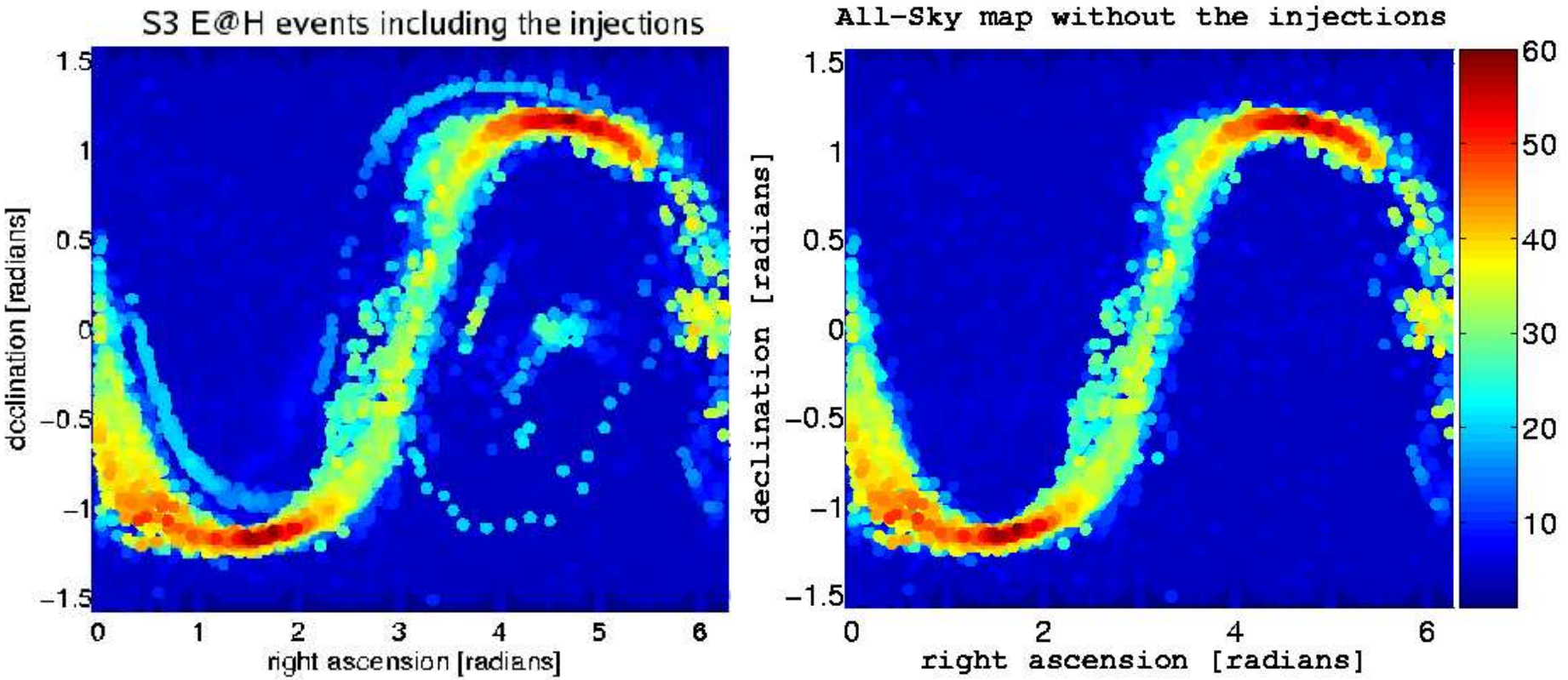
☞ Expected coincidences: $\langle N \rangle \sim 29 - 31$

S3 results: violin modes



Stationary instrumental lines appear on $\boldsymbol{r}(t) \cdot \boldsymbol{n} = 0$ circle in the sky (☞ minimal Doppler modulation)

Complete S3 results



- correctly identified hardware- and software-injections
- all "outliers" ($N \geq 10$) either on $\boldsymbol{r}(t) \cdot \boldsymbol{n} = 0$ circles (☞ stationary lines), or ruled out by follow-up studies (*S4*)

Summary of S3 results

- Excluding hardware- and software- injections: candidates with $N \geq 10$ were found in only 67 frequency-bands (bandwidth 0.1 Hz)
- 59 of those lie on $\boldsymbol{r}(t) \cdot \boldsymbol{n} = 0$ circles: consistent with instrumental lines
- remaining *8 candidates* are low-significance ($N \leq 25$). Either identified as instrumental artefacts (e.g. VME clock), or ruled out by S4 followup-analysis.

☞ no evidence of pulsar-signals found

(at this level of sensitivity)

Improved S4 search

Optimized sensitivity for E@H ($\sim$ 50,000 CPUs):

- add *one spindown* $\dot{f}$ (for $\tau \sim f/\dot{f} \geq 10,000$ years)
- metric search-grids (skygrid $\sim f^2$), mismatch $m = 0.5$
- *optimal* segment-length $T = 30$ hours
- each host: *one* $\mathcal{F}$-statistic search, no coincidence step
- use *"floating threshold"*: return top 13,000 candidates
- each host: all-sky, all spindowns, narrow frequency-band of *variable* width ($\Delta f \propto f^{-3}$)
- workunits last $\sim$ 8 hours, there are $\sim 7 \times 10^6$ WUs
- projected run-time ~ 6 months (currently $\sim$50% done)

E@H future plans

- current S4 search will finish in about 1–2 months
  - ☞ will repeat this search on S5 data (6-12 months)
- CW search group is working on a *fully hierarchical, multi-IFO* search (Hough+$\mathcal{F}$-statistic)
- *Optimize* for sensitivity: number and length of stacks, mismatches, improved metric grids, ...
- ☞ aim: provide the most sensitive search possible for continuous GWs from spinning neutron stars