Einstein@home:

Tapping into global interest in LIGO for gravitational pulsar searches

Teviet Creighton

for

The Einstein@home team (B. Allen, et al.)

`http://einstein.phys.uwm.edu`

Summary

- Searches for gravitational waves (GWs) from spinning neutron stars are *computationally limited*

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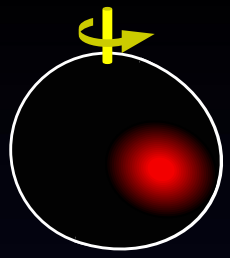
- Current status:

  - 3rd science run (S3) analysis completed and published on the web
  - S4 crunching is complete and post-processing is beginning
  - S5 data are now being sent out

Outline

I. GWs from neutron stars
II. Einstein@home & BOINC
III. Einstein@home timeline
IV. S3 method & results
V. Einstein@home lessons
VI. S4 & S5

GWs from neutron stars



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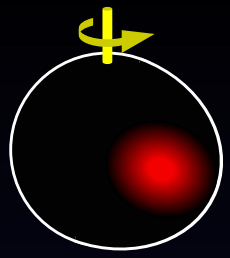

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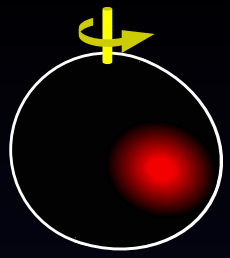

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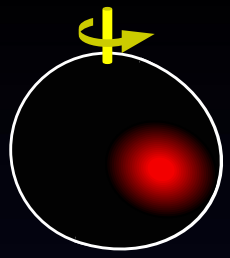

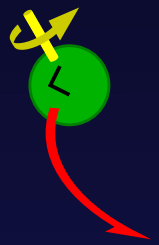

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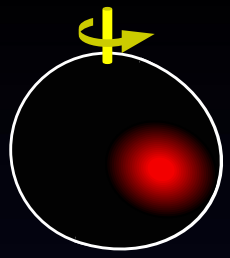

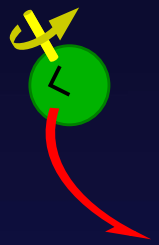

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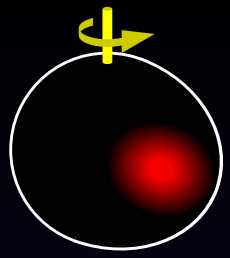

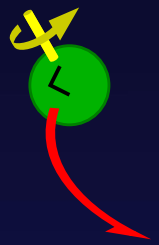

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  ⇒ Length of templates, and thus sensitivity of search, are *computationally limited*

Einstein@home goals

- **Science:**
  - Distributes most computational work to computers in general public
  - Aimed at *detection* of GWs from pulsars (not upper limits)
  - Uses **B**erkeley **O**pen **I**nfrastructure for **N**etwork **C**omputing (**BOINC**)

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- **Outreach:**
  - Launched at AAAS meeting, Feb. 19 2005
  - Cornerstone of APS World Year of Physics 2005 outreach activities
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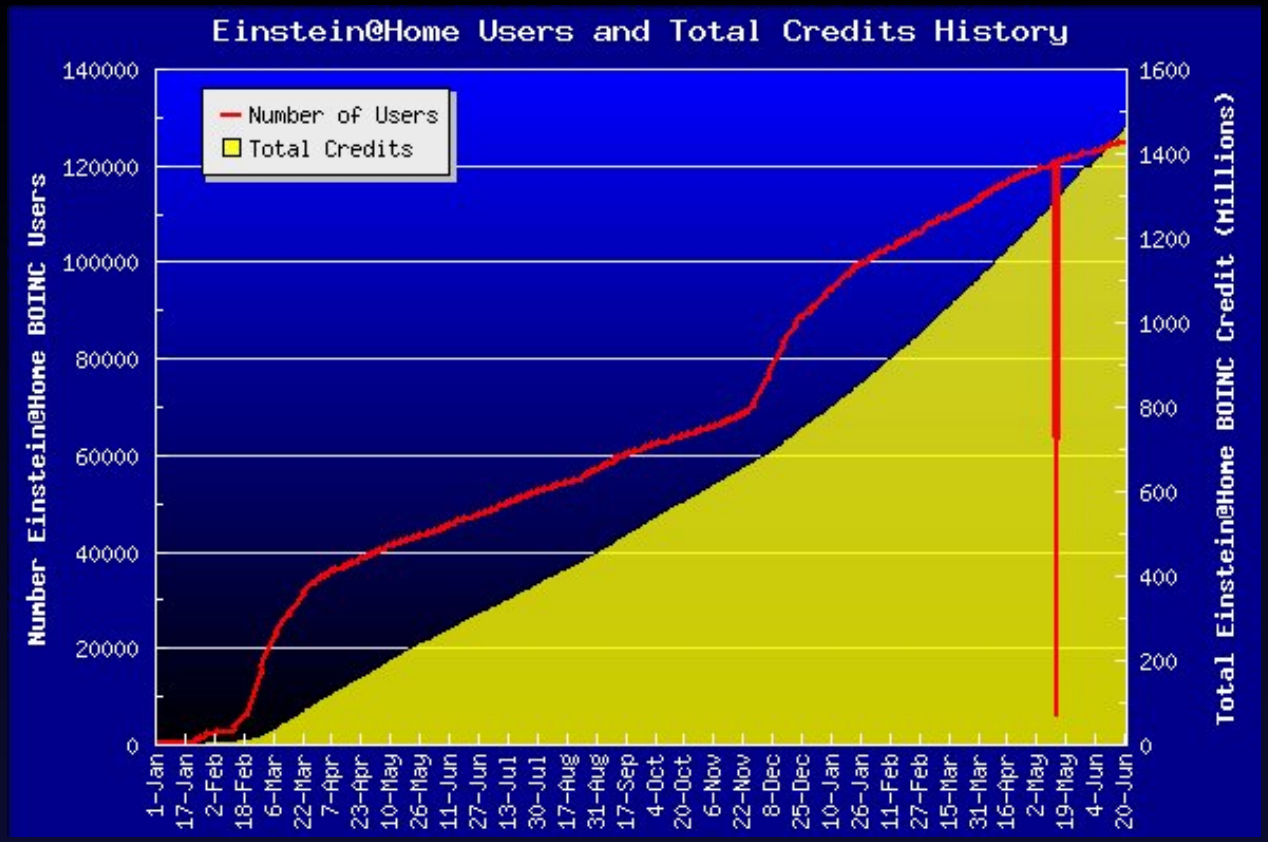

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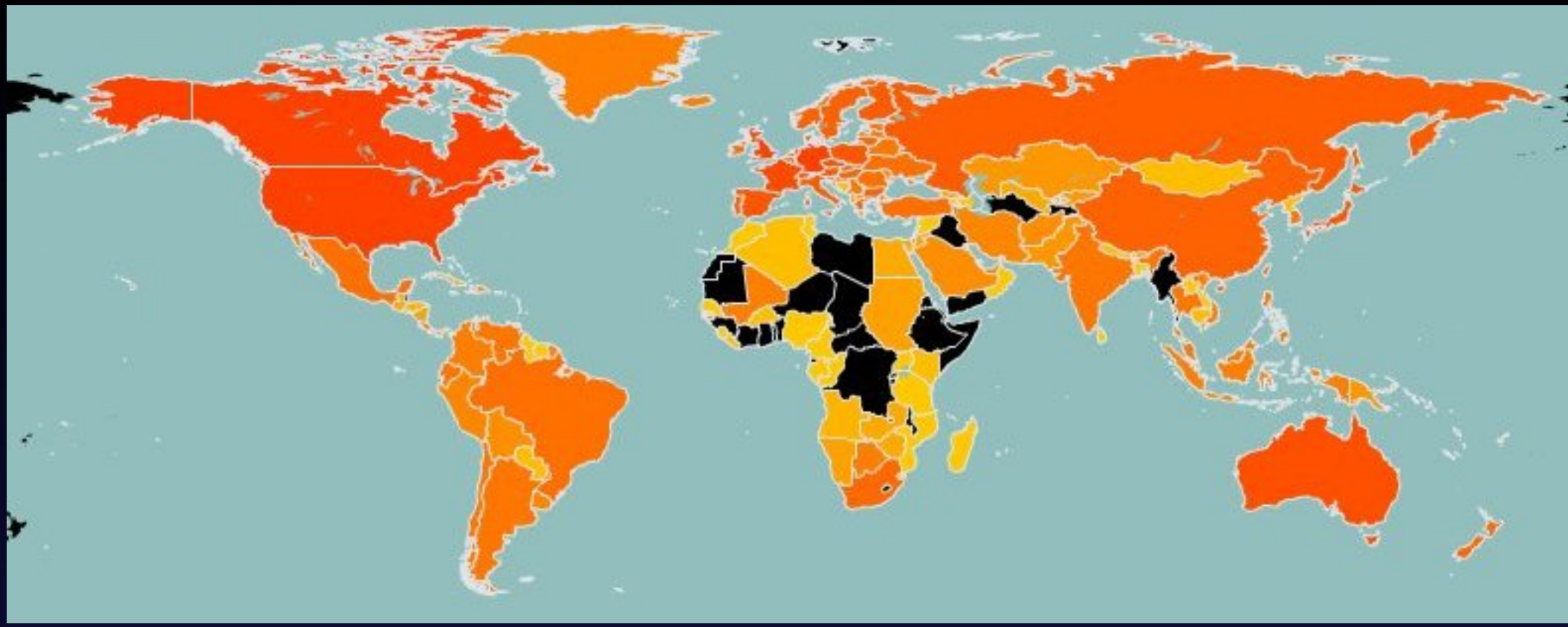

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  - ⋆ Growth of Einstein@home over time. . .
  - ⋆ Truly a global endeavour!

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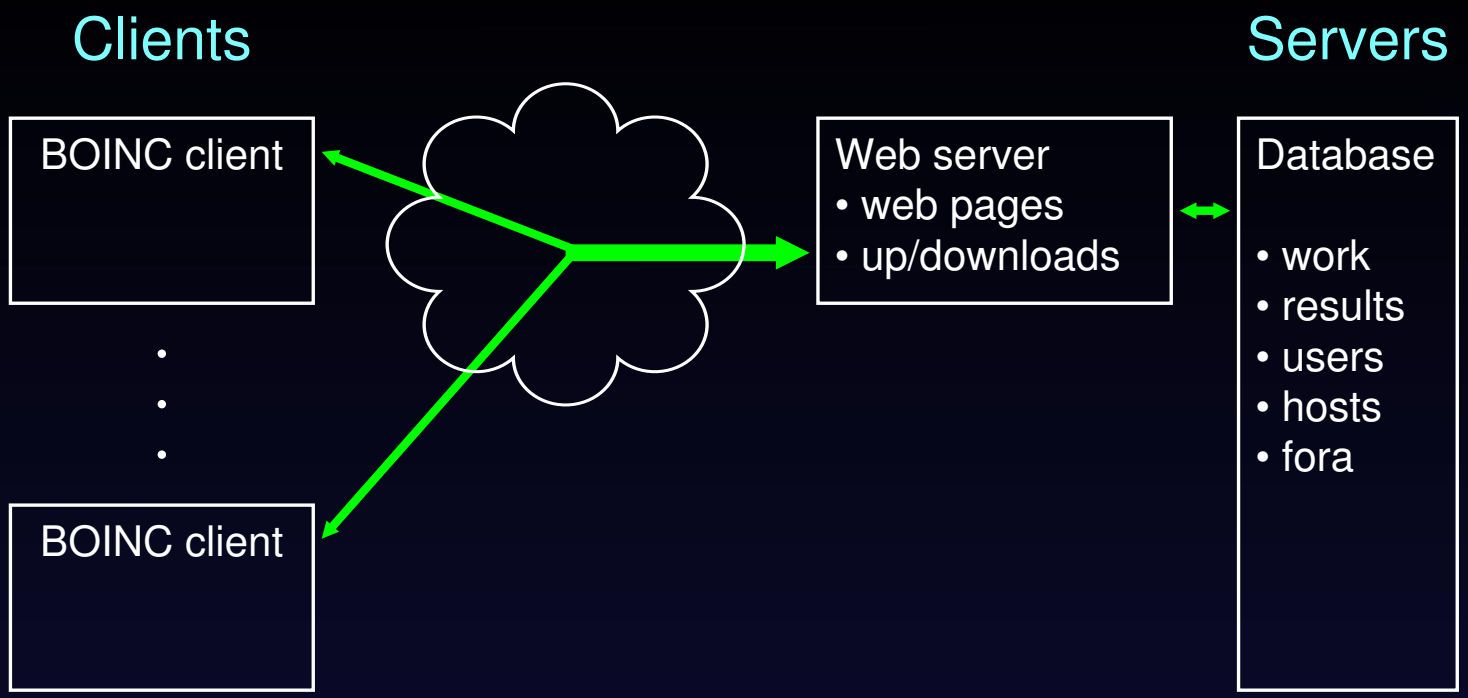

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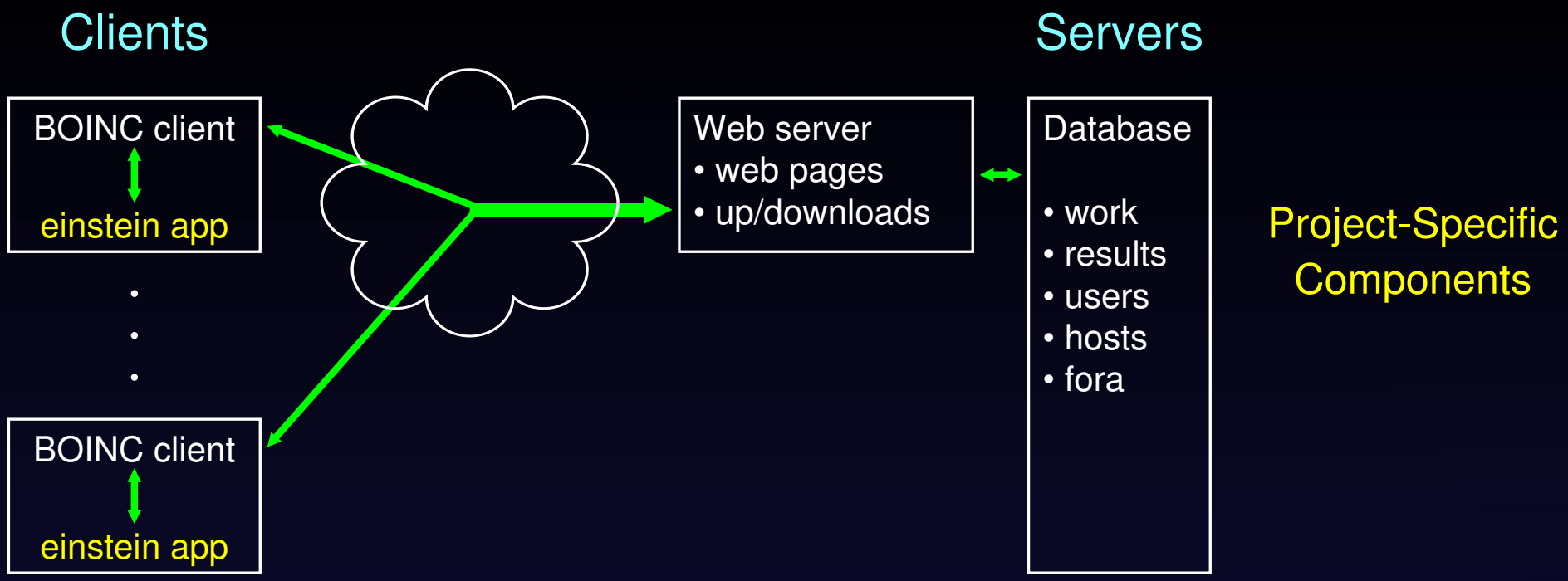

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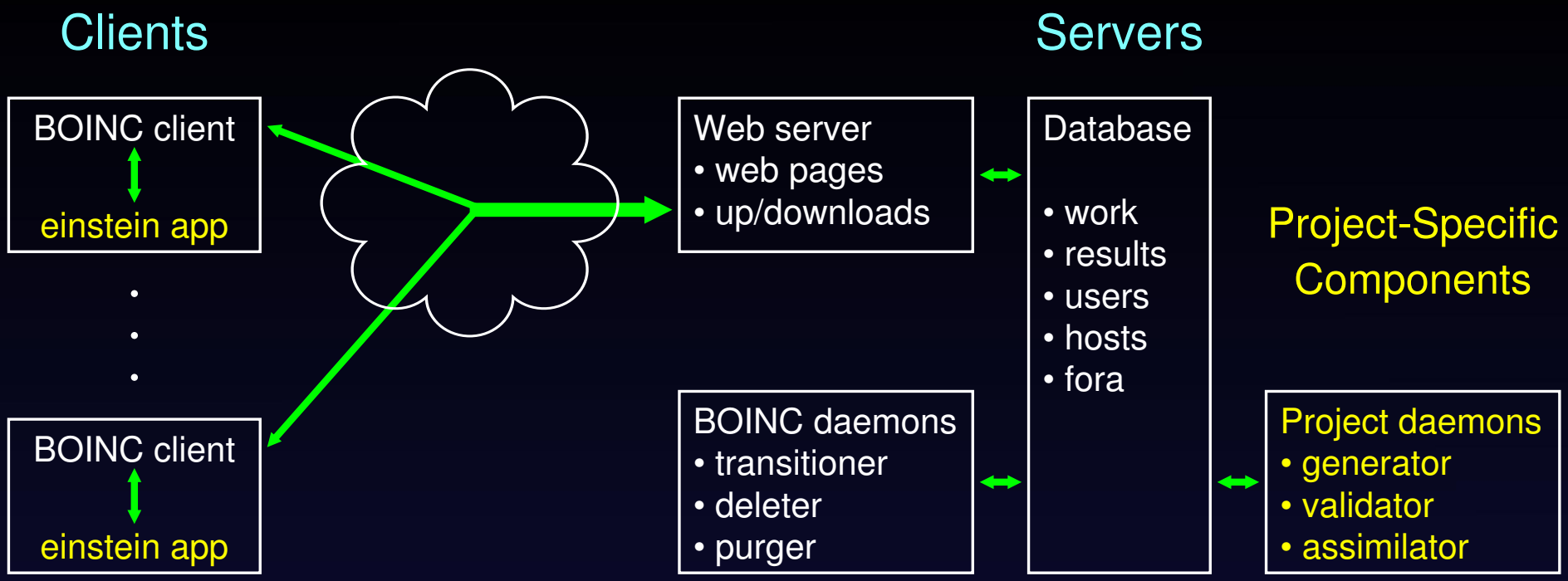

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- BOINC client installs and runs analysis application(s)
  - Can update application on the fly
- Other BOINC and project daemons schedule workunits and process results

Einstein@home timeline

- Spring 2004: Development of Einstein@home begins
- November 2004: Unofficial test launch
- 19 February 2005: Official public launch, analyzing S3 data
- 3 May 2005: Second S3 search using calibrated, cleaned data
- 27 June 2005: Started preliminary search of S4 data
- September 2005: Published partial S3 results on Einstein@home website
- 24 December 2005: Started improved and optimized S4 search
- 16 June 2006: Sent out last of S4 data, started on S5 data
- Where we stand. . .

Einstein@Home - Server Status

Einstein@Home server status as of 11:11 PM UTC on Wednesday, 21 June 2006 (updated every 20 minutes).
The Einstein@Home main server has been continuously up for 9 days 2 hours 16 minutes.

Server status

Program	Host	Status
Web server	einstein	Running
Einstein work generator	einstein	Running
BOINC database feeder	einstein	Running
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Download mirror status

Site	Status	Last failure
Albert Einstein Institute	Running	164 h 6 m ago
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S5 search progress

Total needed	Already done	Work still remaining
16,446,454 units	183,476 units	16,262,978 units
100 %	1.116 %	98.884 %
365.7 days	4.1 days	361.7 days (estimated)

Users and Computers

USERS	Approximate #
in database	200,663
with credit	125,388
registered in past 24 hours	130

HOST COMPUTERS	Approximate #
in database	433,259
registered in past 24 hours	869
with credit	246,773
active in past 7 days	71,945
potential floating point speed[1)]	102.8 TFLOPS
floating point speed[2)]	50.8 TFLOPS

Work and Results

WORKUNITS	Approximate #
in database	598,775
with canonical result	363,326
S4 WU (no canonical result)	140,499
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RESULTS	Approximate #
in database	1,687,813
unsent	17,371
in progress	280,297
deleted	1,025,140
valid	1,002,190
valid last week	694,205
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Oldest Unsent Result	5 d 14 h 22 m

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Over 70 000 “nodes” running Einstein@home!

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(we expect things to speed up)

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Update: has jumped to >70 Tflops in last week!

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- *Candidates* have $2\mathcal{F} \geq 25$ in a given 10h stretch
- *Coincident* if they occur with $\Delta f \leq 10^{-3}$Hz, $\Delta\Omega \leq 0.02$ in 2 or more stretches

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- *Coincident* if they occur with $\Delta f \leq 10^{-3}$Hz, $\Delta\Omega \leq 0.02$ in 2 or more stretches
- For each sky position and frequency, count number of coincidences N (≤ 60)

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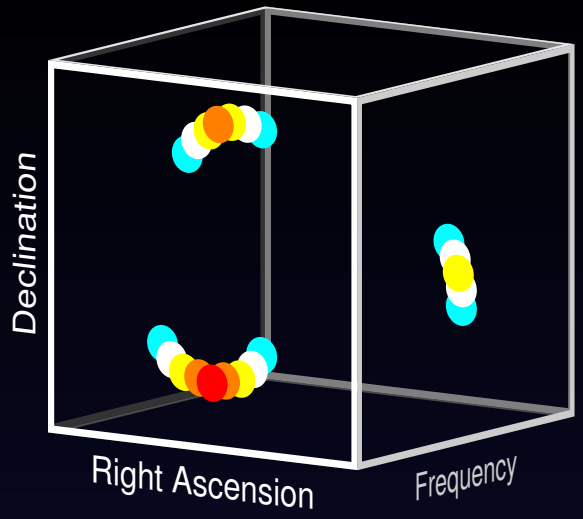
- Individual hosts are unreliable (overclocking, cheating)
  $\Rightarrow$ Each workunit must have same result from at least 3 hosts

S3 Results: Visualization



- 3 search parameters: Right Ascension α, Declination δ, and Frequency f
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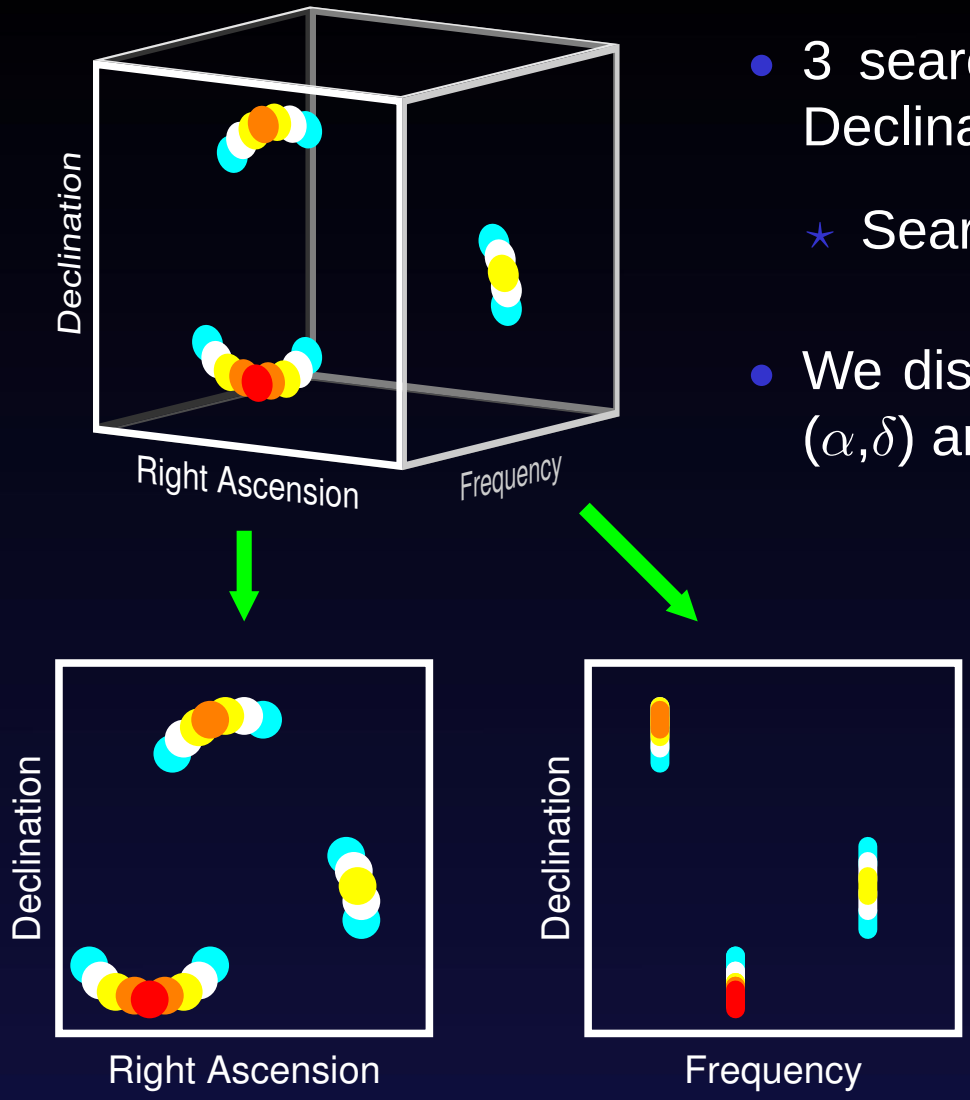

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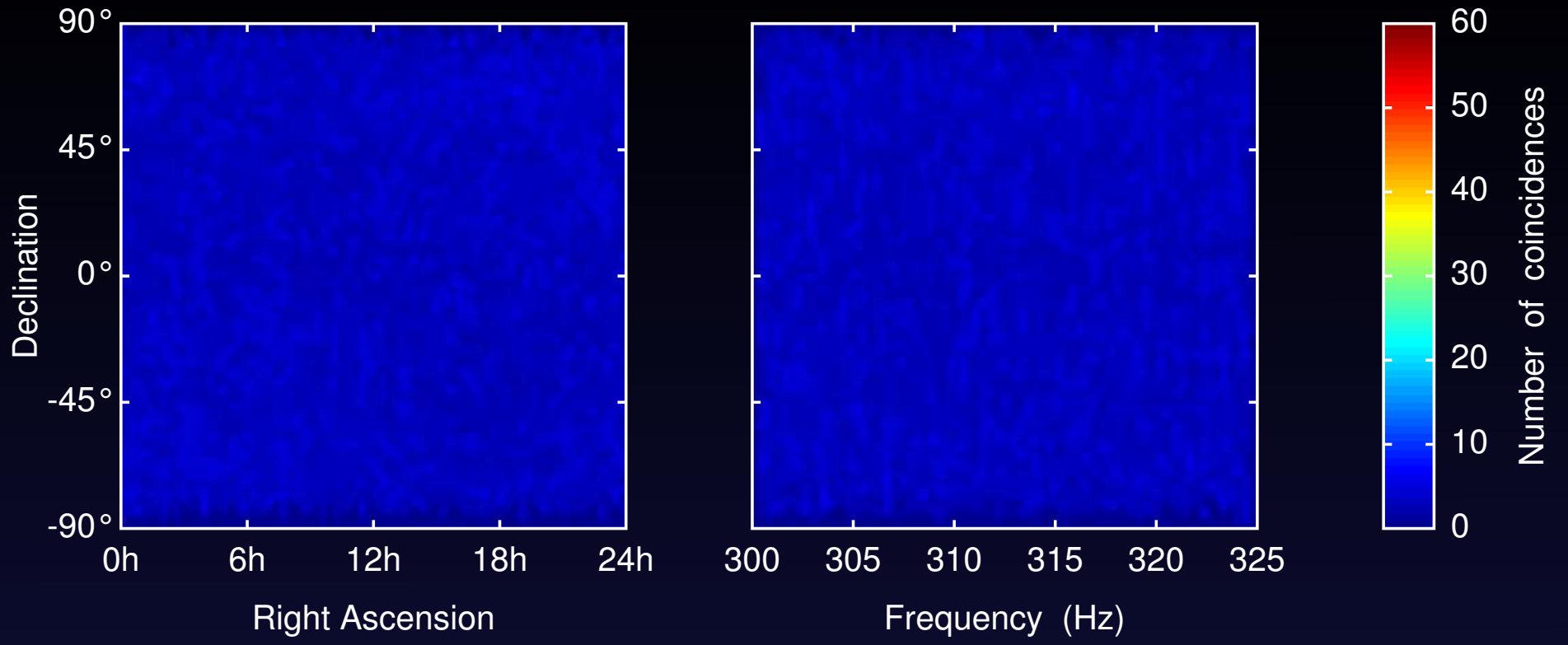
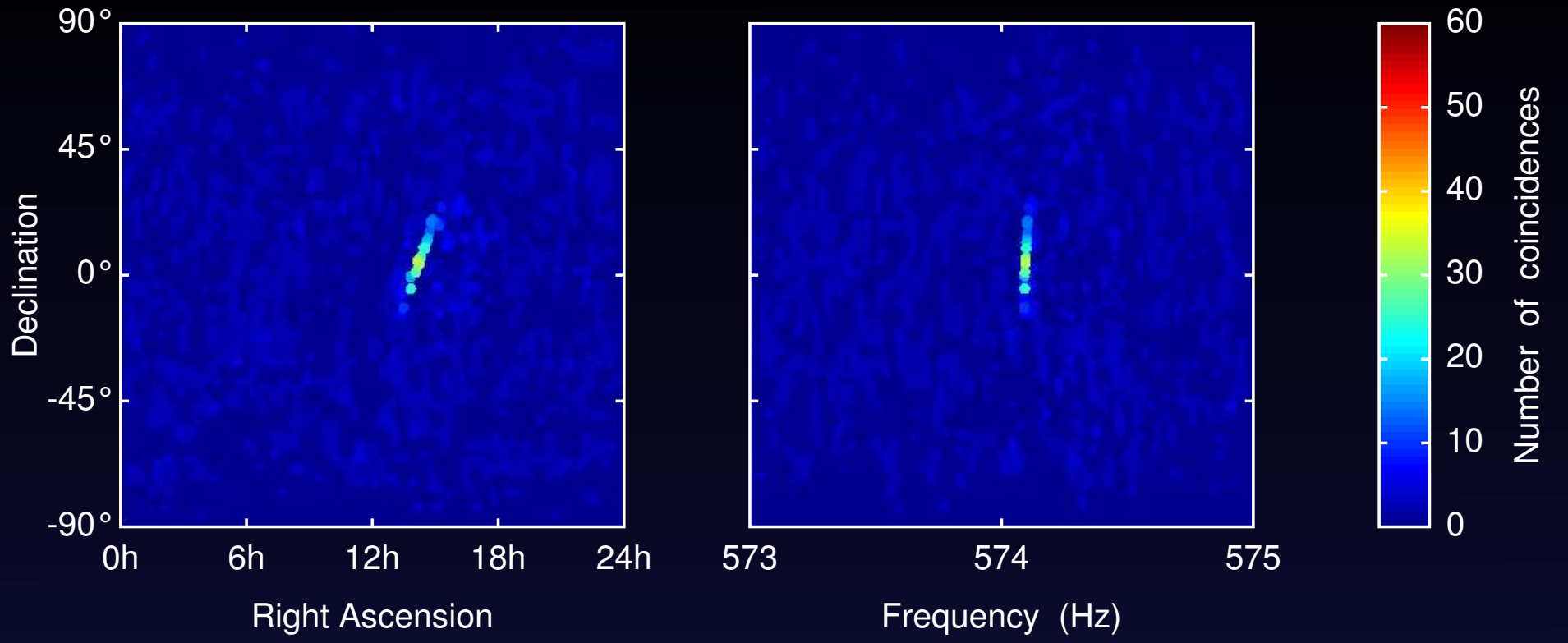
- We display peak value of N projected onto (α,δ) and (f,δ) planes

S3 Results: Clean band



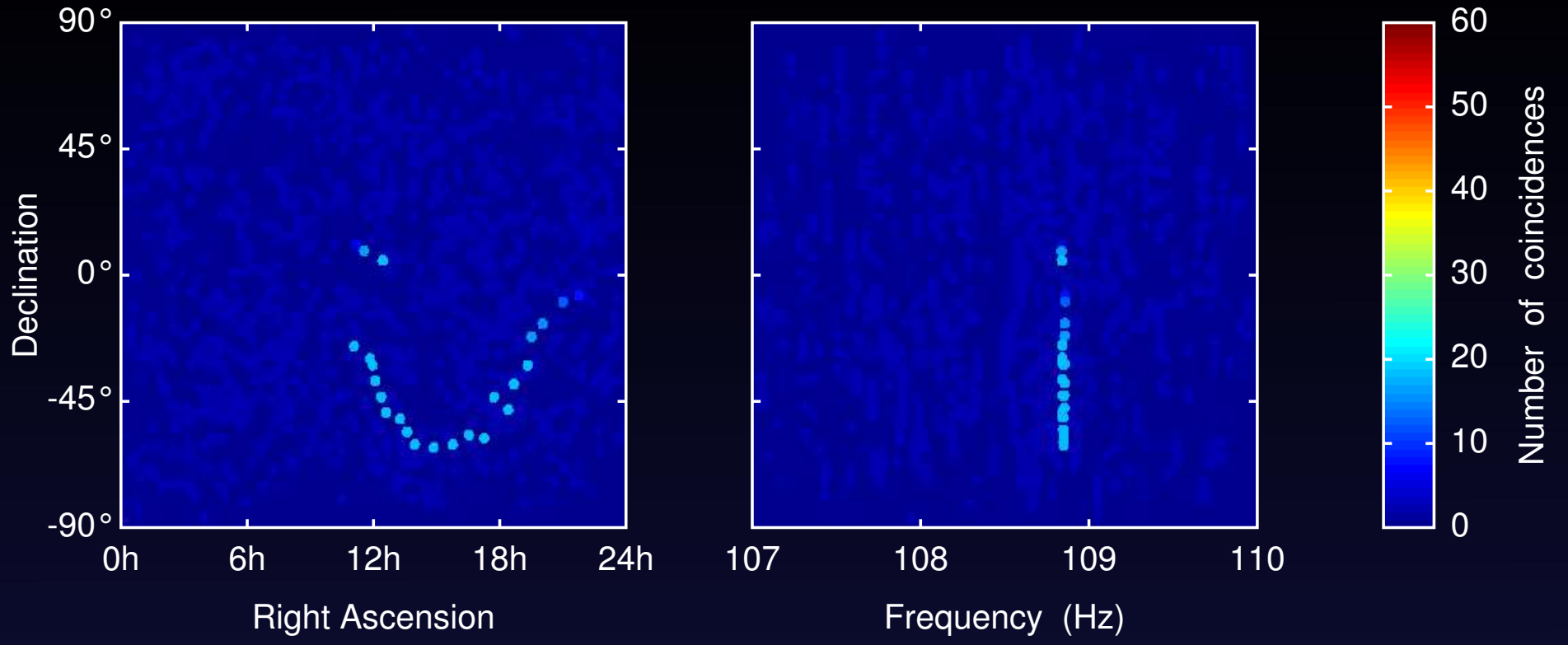
- Scatter plot of coincidences in a “good” 25Hz band
- Number N of coincidences typically $\leq$6: statistically insignificant

Software injection



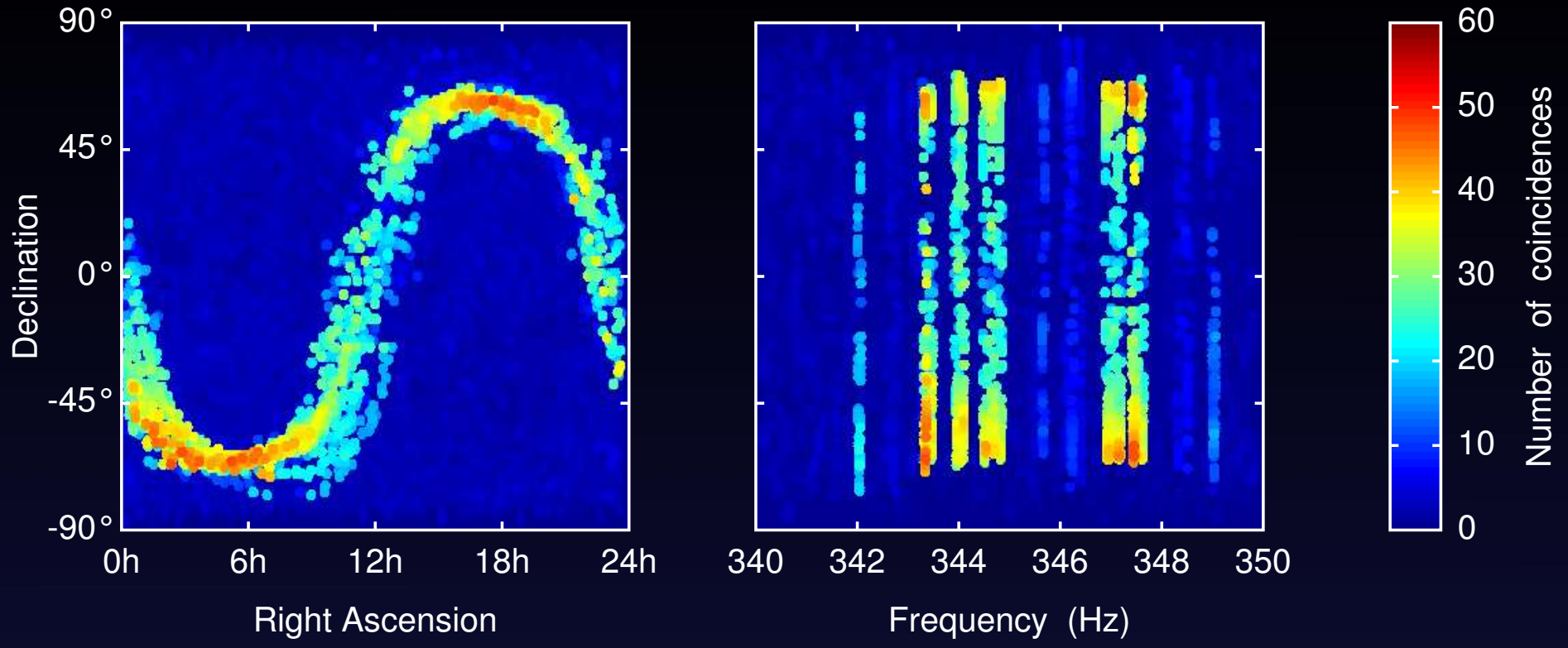
- Simulated source with h_0=6.2×10^{-23}
- Smeared out due to short observation time ($\sim$2 months)

Hardware injection



- Simulated source with h_0=1.6×10^{-23}
- Only on 1/3 to 2/3 of time $\Rightarrow$ poorer resolution

Violin modes



- . . .and other constant-frequency artifacts
- Smeared into a characteristic band across sky

Bad slices in (α, δ, f)

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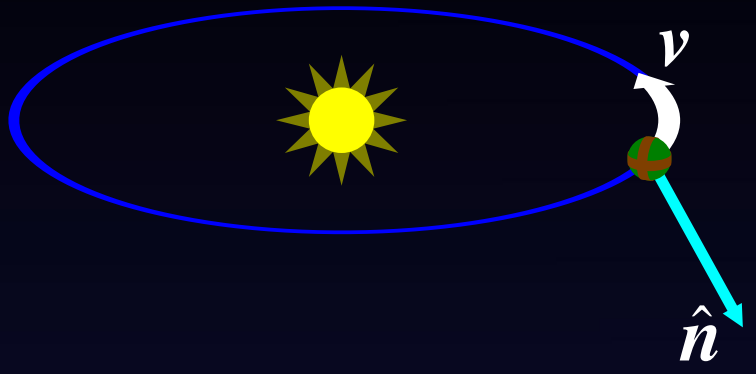

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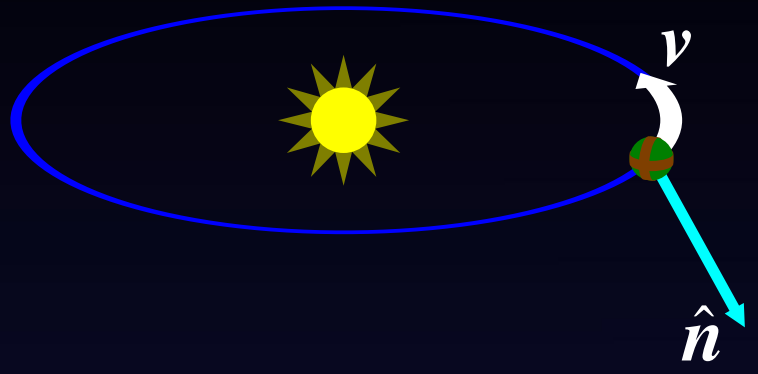

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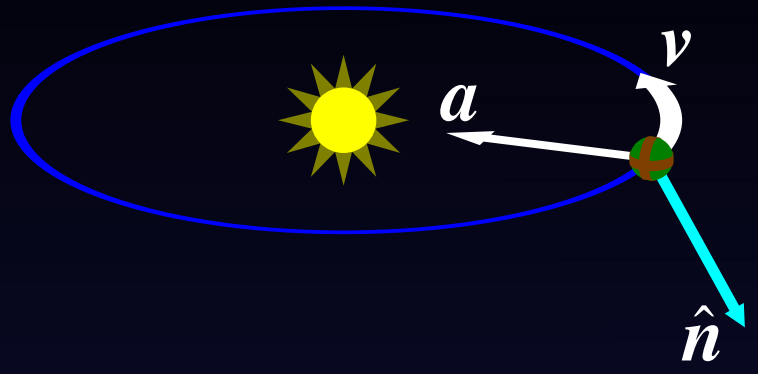

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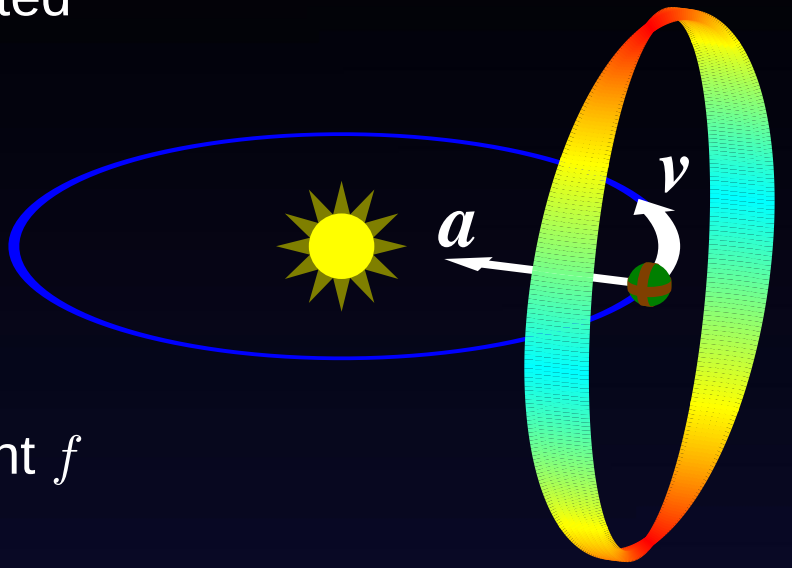

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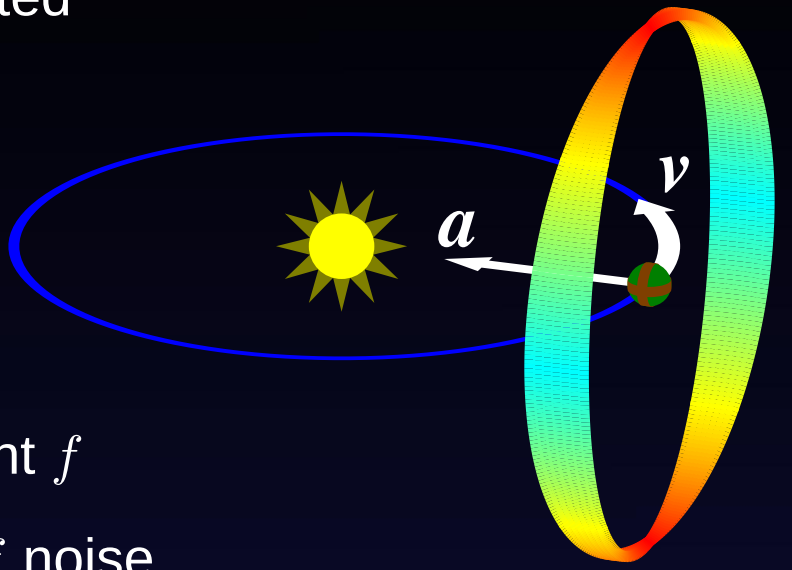

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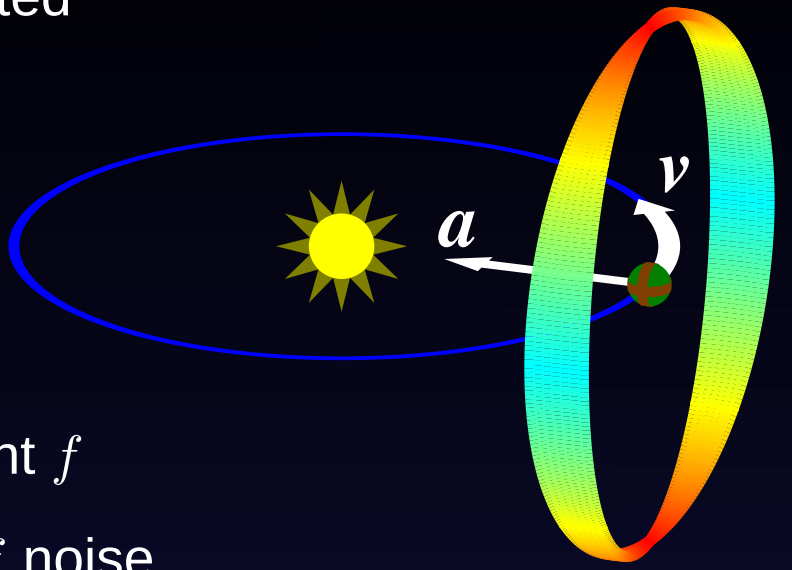

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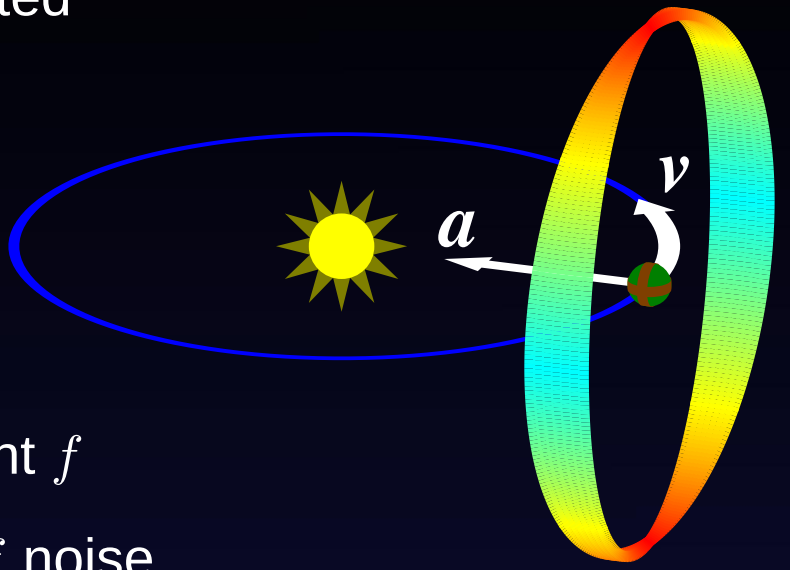

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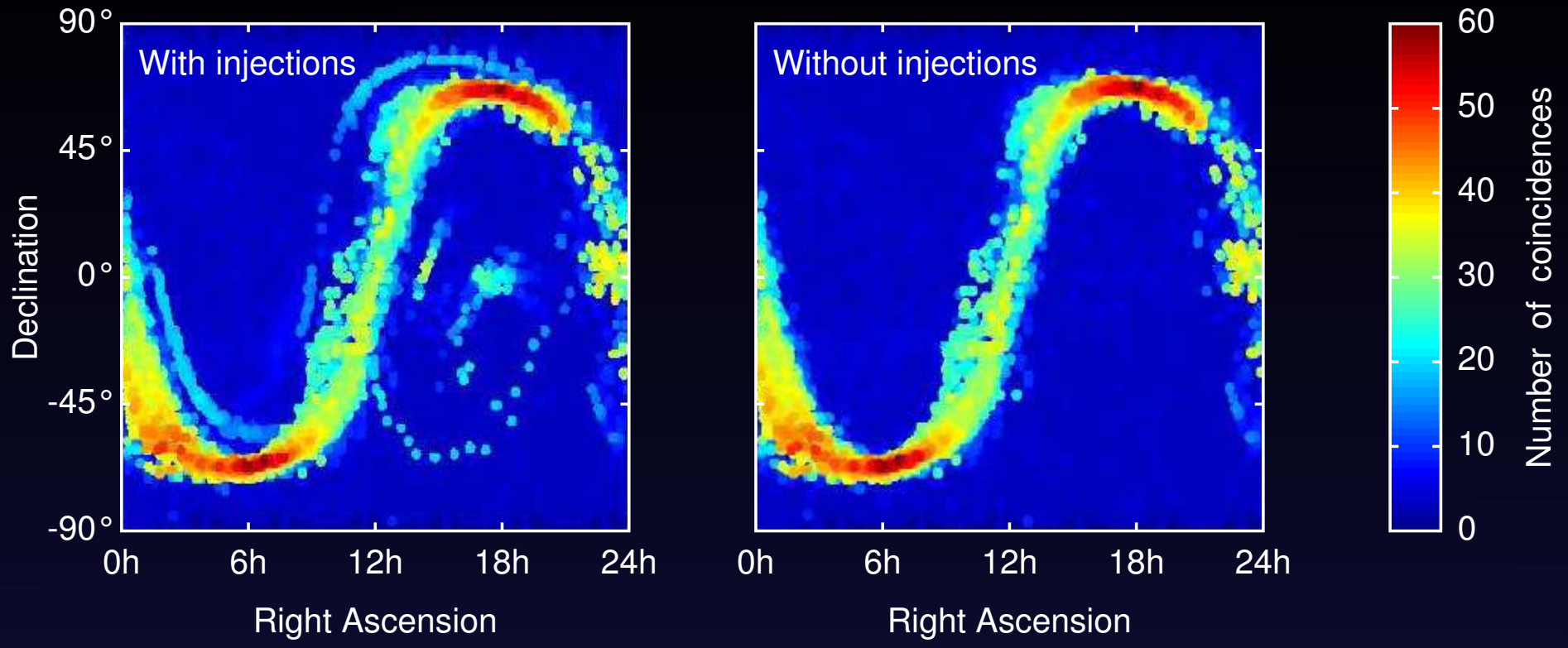
- Longer observations (many months) will reduce this effect
  - ⋆ But ecliptic poles will always be bad zones

S3: Final results



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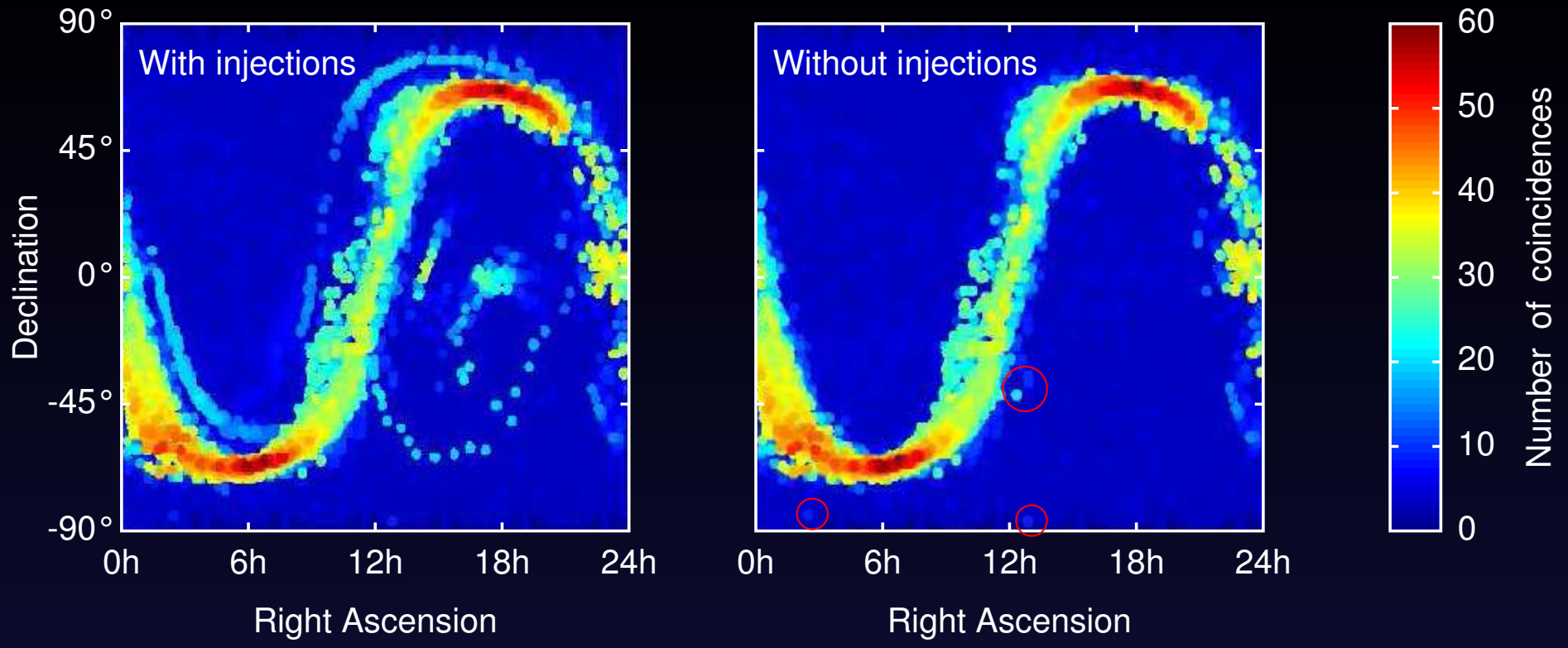

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⇒ No evidence of pulsar signals found

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- Source of motivation: the BOINC “credit” (cumulative flops contributed)
  - Since BOINC allows users to spread their cycles among many projects, users will migrate to the project with the best return
  - Users like optimized applications that give them better performance
  - Some users will cheat for credit: this turned out to be main reason for keeping triple-redundant validation

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- **Status:** Started sending out workunits; estimated 6 to 12 months
  - ⋆ Server side has spare capacity
  - ⇒ Time to recruit more users!