



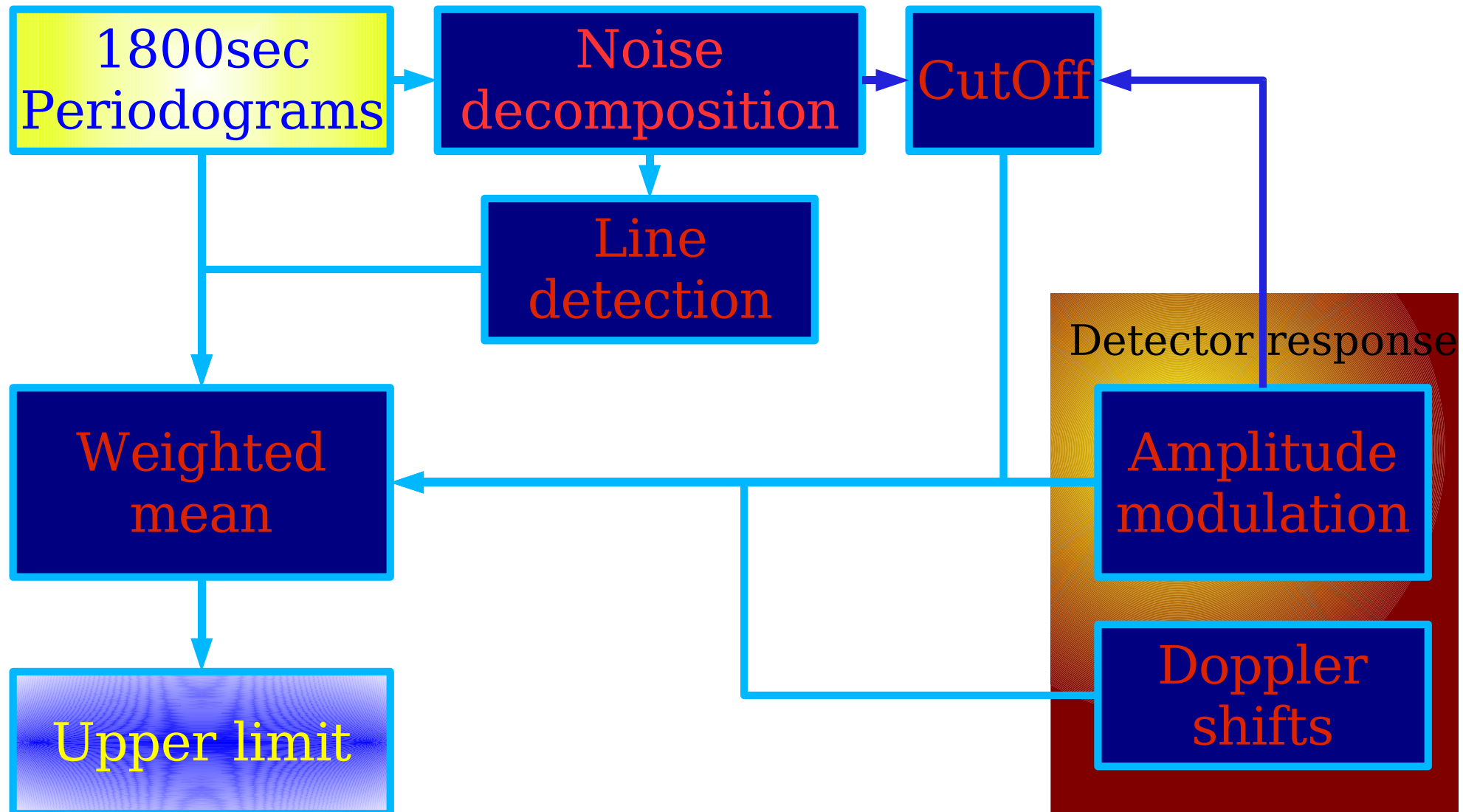
Broadband Search for Continuous-Wave Gravitation Radiation with LIGO

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Challenges of search for CW gravitational waves

- Gravitational waves are weak – need to average over long time periods
- Several parameters to search for: frequency, sky position, spindown, polarization
- Coherent methods are very sensitive, but result in enormous search space size – broadband, all sky search is impractical for large time base
- **PowerFlux** – place sky-dependent upper limits and detect signals by averaging power. Practical for all-sky broadband searches.

PowerFlux analysis pipeline



PowerFlux results

- PowerFlux produces a 95% CL upper limit for a particular frequency, sky position, spindown and polarization.
- Too much data to store, let alone present – the number of sky positions alone is $\sim 10^5$ at low frequencies and grows quadratically with frequency
- The upper limit plots show maximum over spindown range, all polarizations and a particular spindown-dependent sky area
- We also present a simple formula that approximates background curve within $\pm 50\%$

“S parameter”

When S is closer to 0 susceptibility to stationary artifacts increases

$$S := s + \frac{\overbrace{\vec{u} \times \vec{v}_{\text{avg}}}^{\text{Average detector acceleration}}}{c} f \cdot \hat{\vec{r}}$$

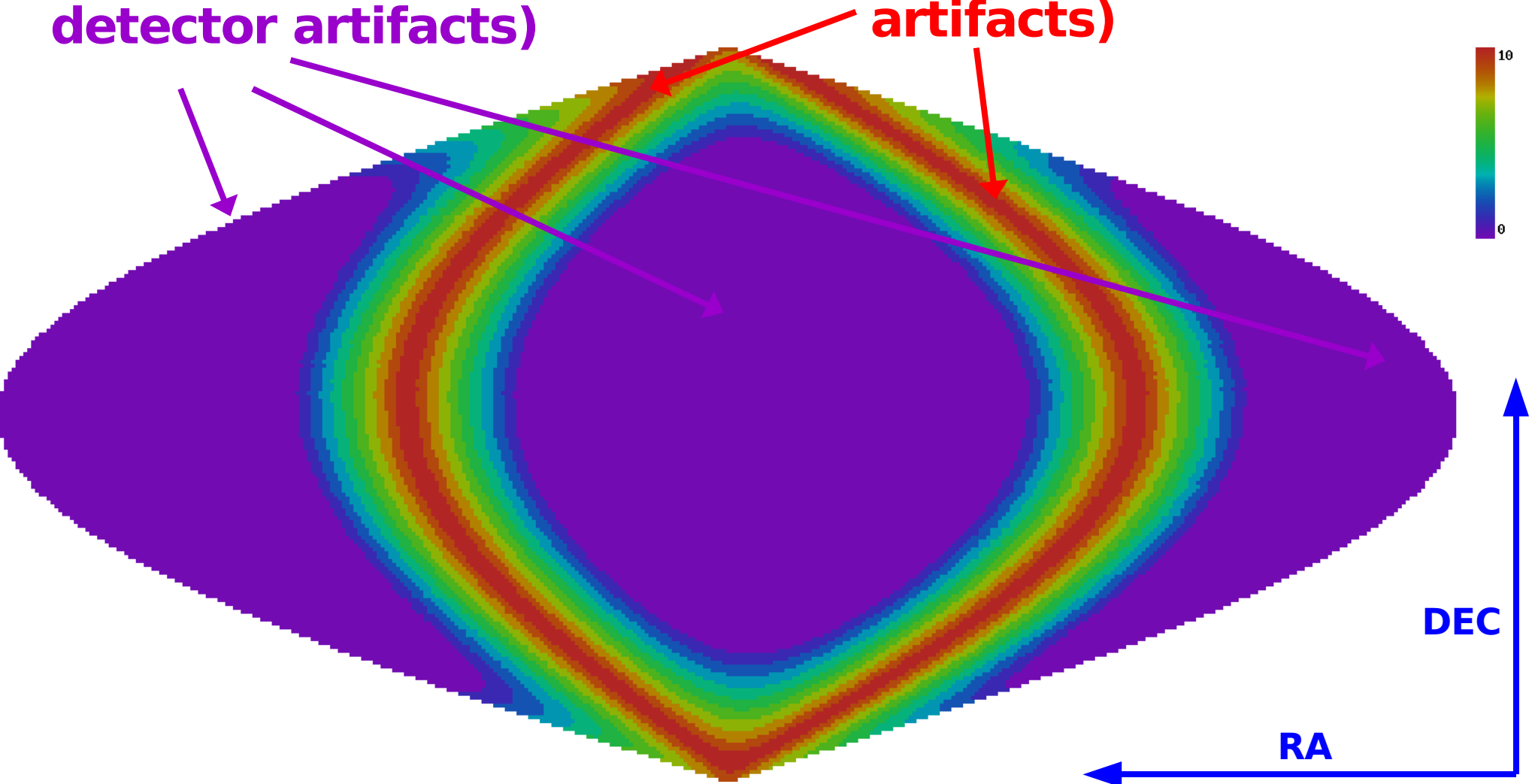
Diagram illustrating the components of the S parameter equation:

- s : Spindown (Hz/s)
- $\vec{u}$: Earth orbit angular velocity
- $\vec{v}_{\text{avg}}$: Average detector velocity
- c : Speed of light
- f : Frequency
- $\hat{\vec{r}}$: Unit sky position vector

Doppler Skybands

Skyband 0 (good – only exceptionally strong detector artifacts)

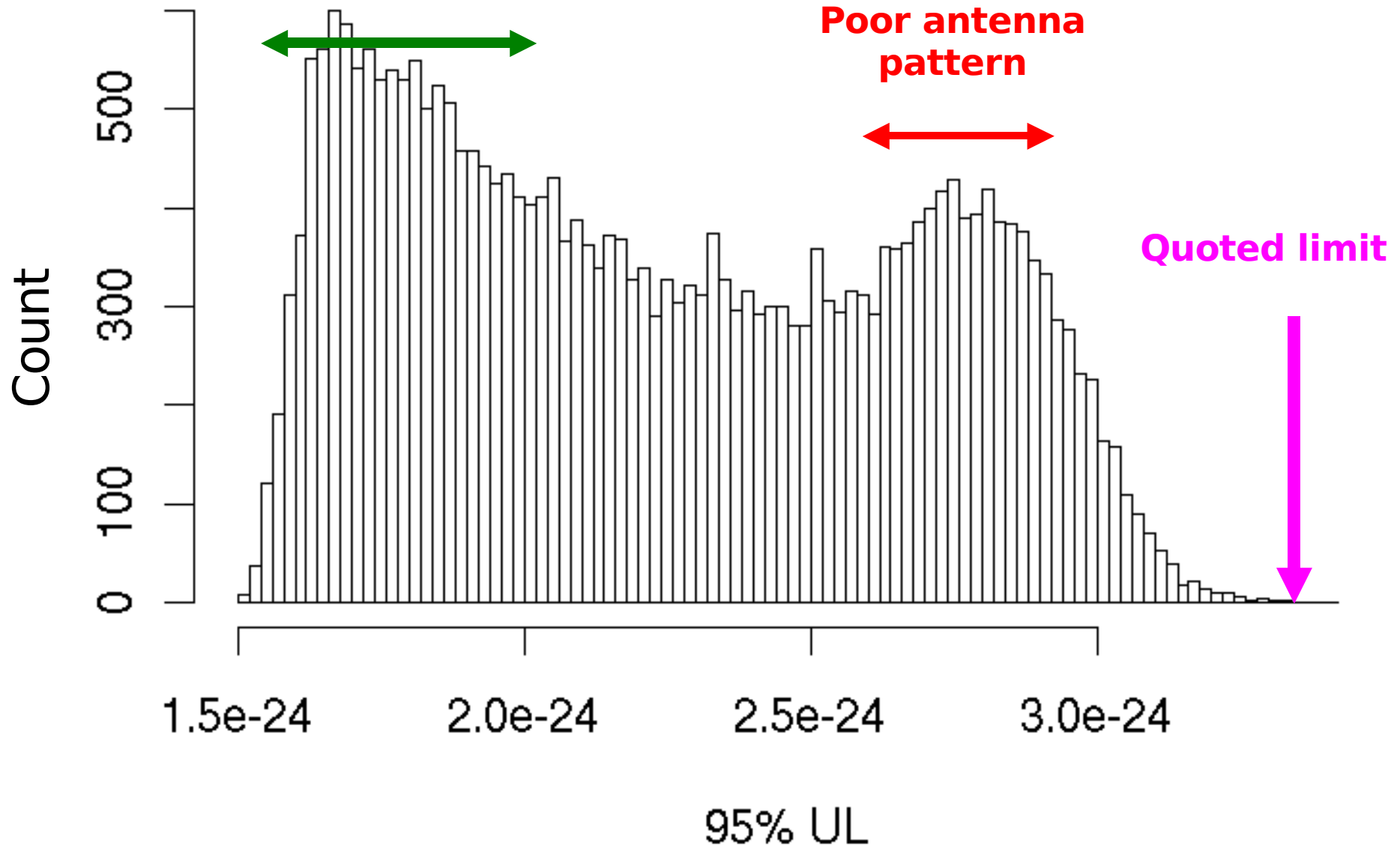
Skyband 10 (worst – many detector artifacts)



Sample of 95% CL Upper Limits on $h_{\text{linear}} = 0.5 * h_{0\text{-worst case}}$ (sky band 0)

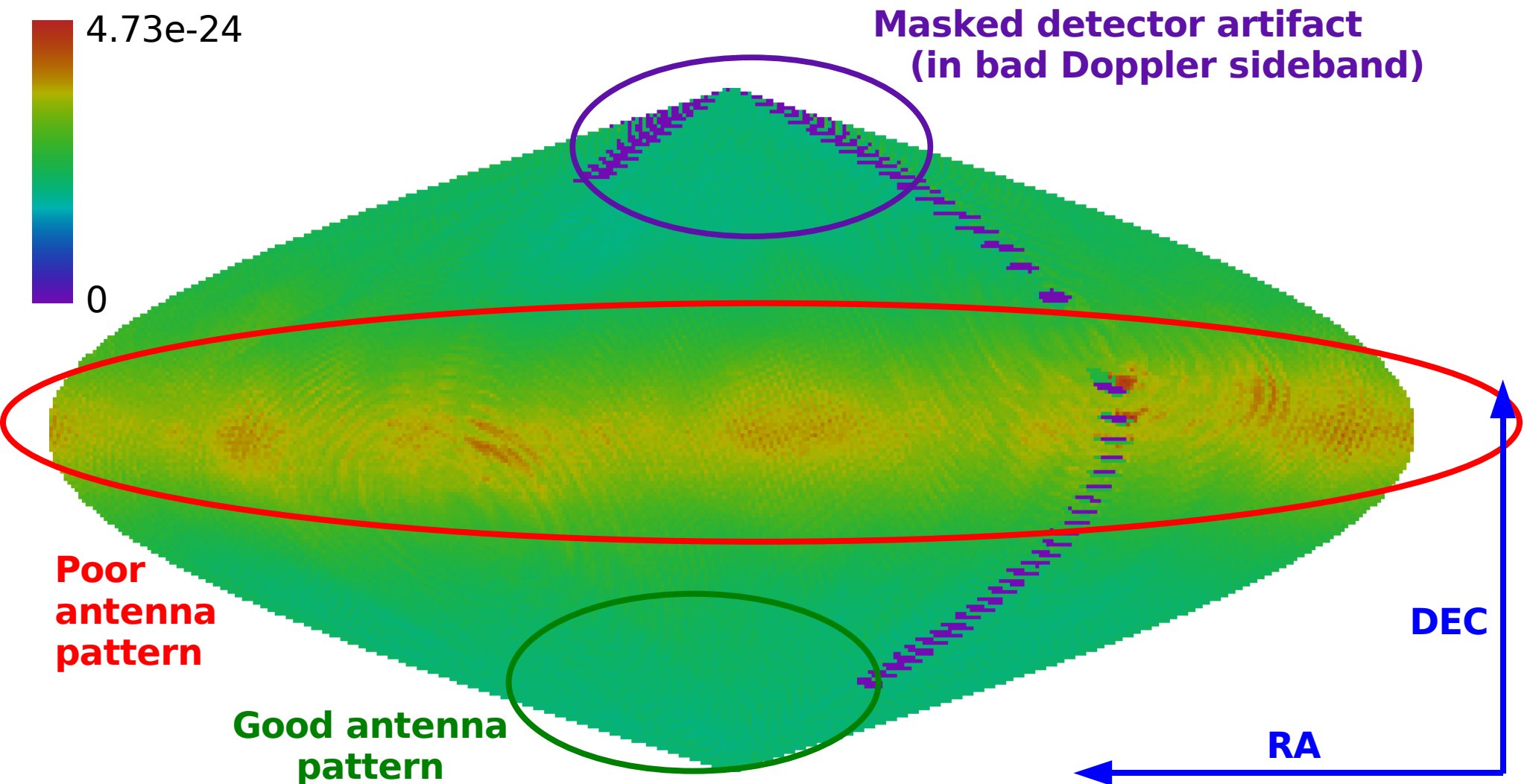
Good antenna pattern / noise

Poor antenna pattern



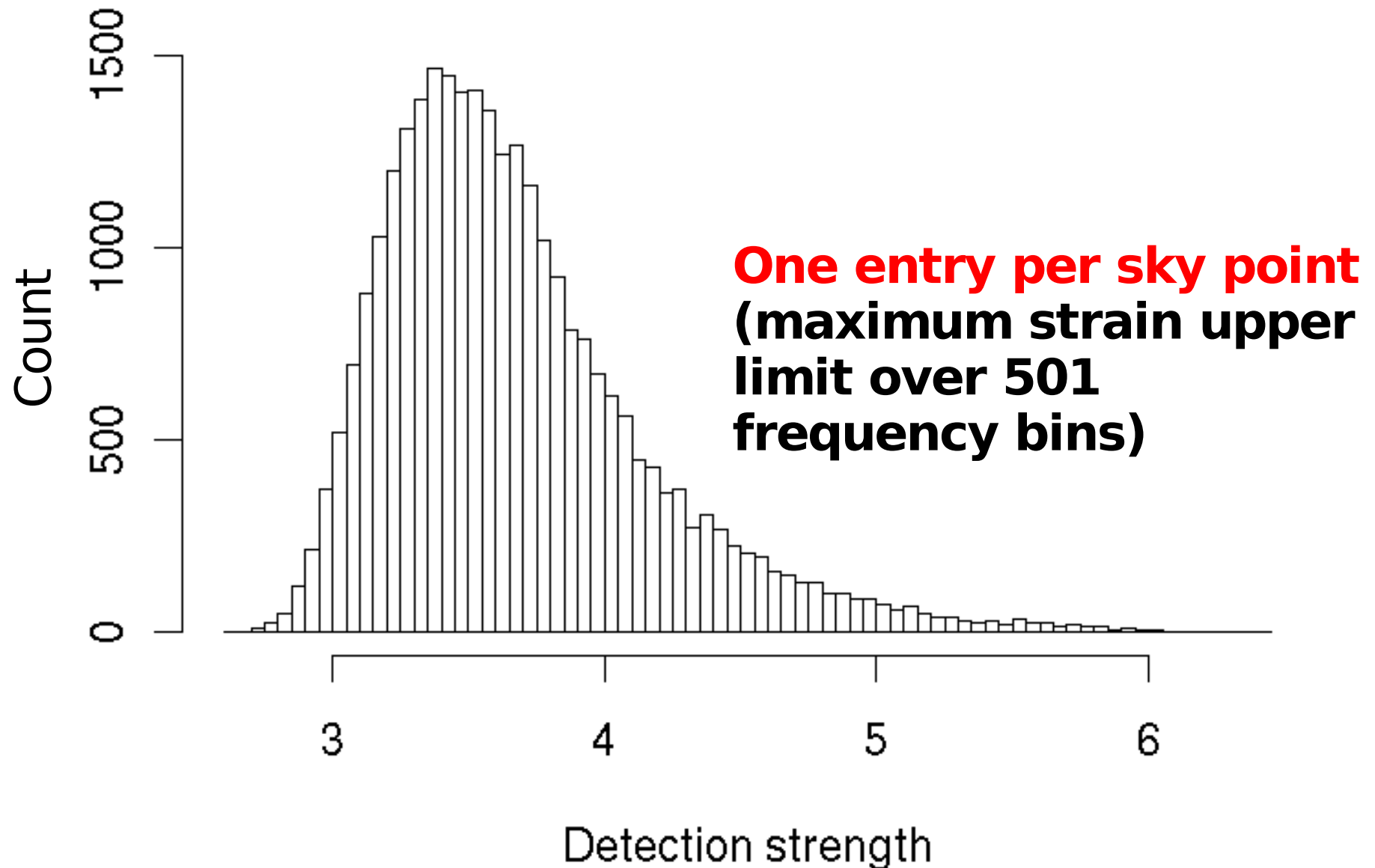
Corresponding skymap of strain limits

(Hanford 4km, 149-149.25 Hz, spindown 0)



Corresponding Signal-to-Noise Ratios

Background distribution



S4 run summary

- Frequency range: 50-1000 Hz
- Spindown range: 0 through -1e-8 Hz/s
- Background (cyan curve) can be described by the following formula:

$$Strain = 4 \cdot 10^{-26} \cdot f^{0.9} + \frac{3 \cdot 10^{-17}}{f^{3.5}}$$

Here f is frequency in Hz

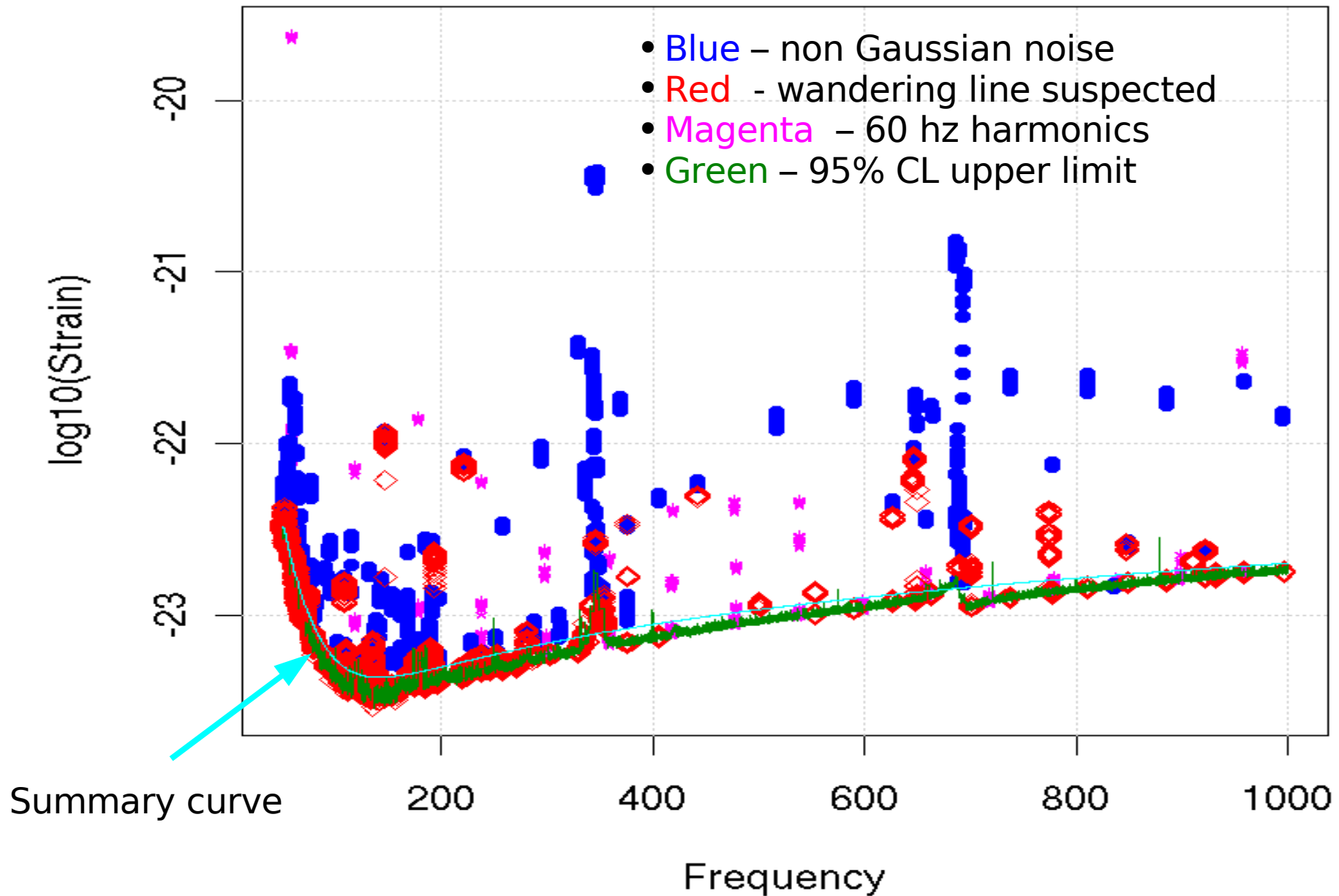
- Skyband 0 (maximum over which is shown on plots) is defined by

$$abs(S) > 3.08e-9 \text{ Hz/s}$$

Livingston 4km upper limits are slightly lower than the summary curve, but not as clean in low frequency range

S4 run results

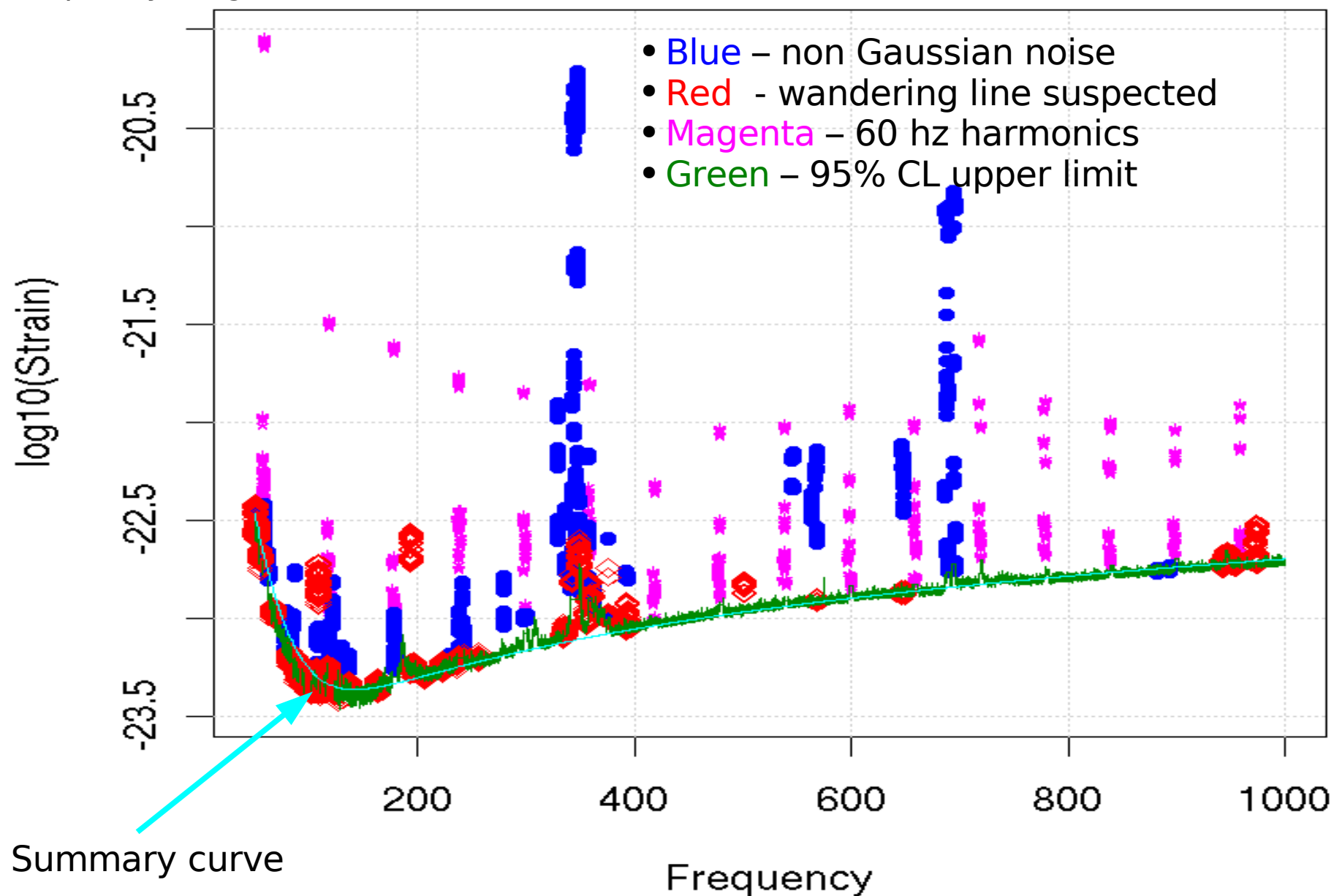
Livingston 4km



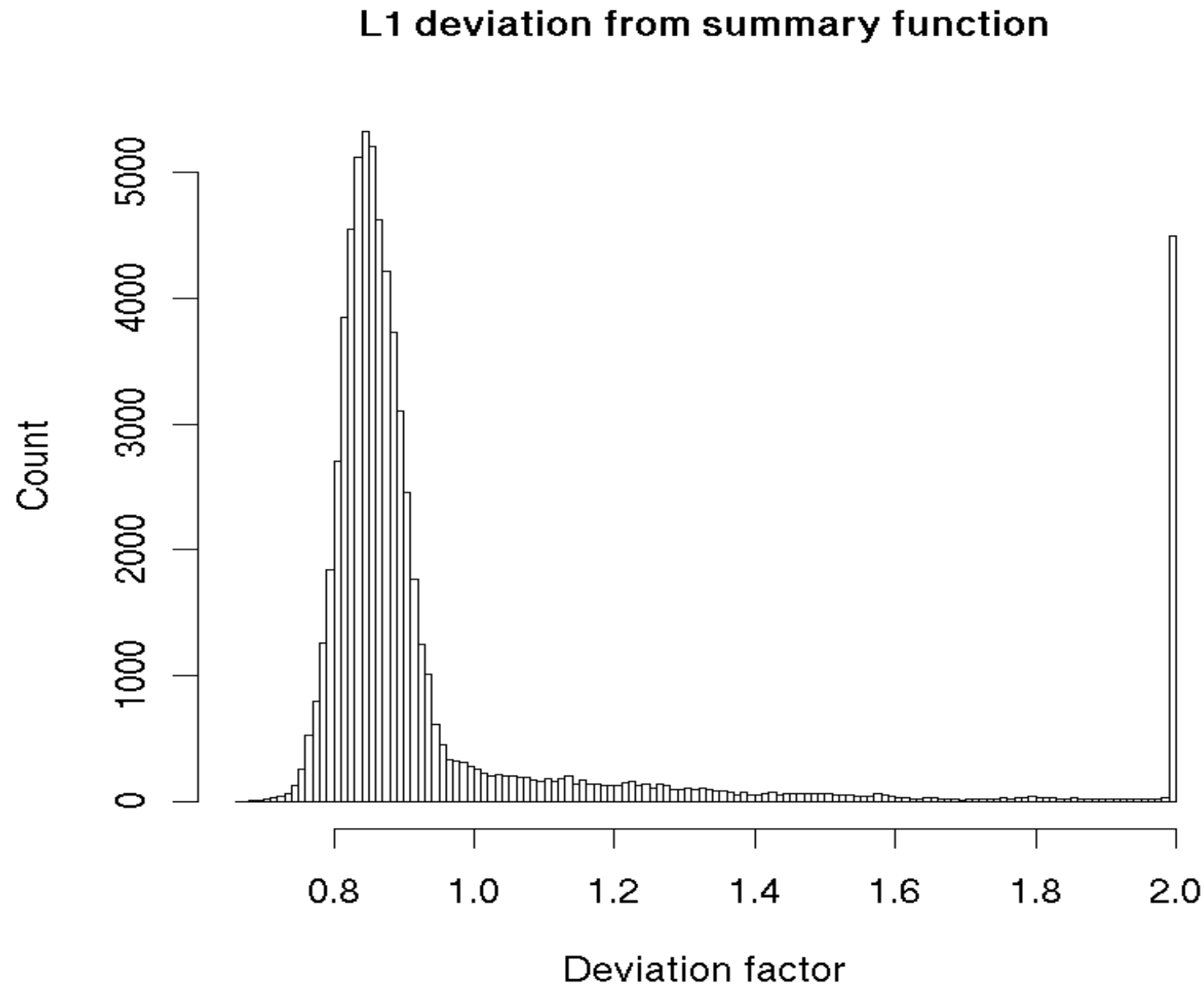
Hanford 4km upper limits
are slightly higher than
the summary curve, but
much cleaner in low
frequency range

S4 run results

Hanford 4km



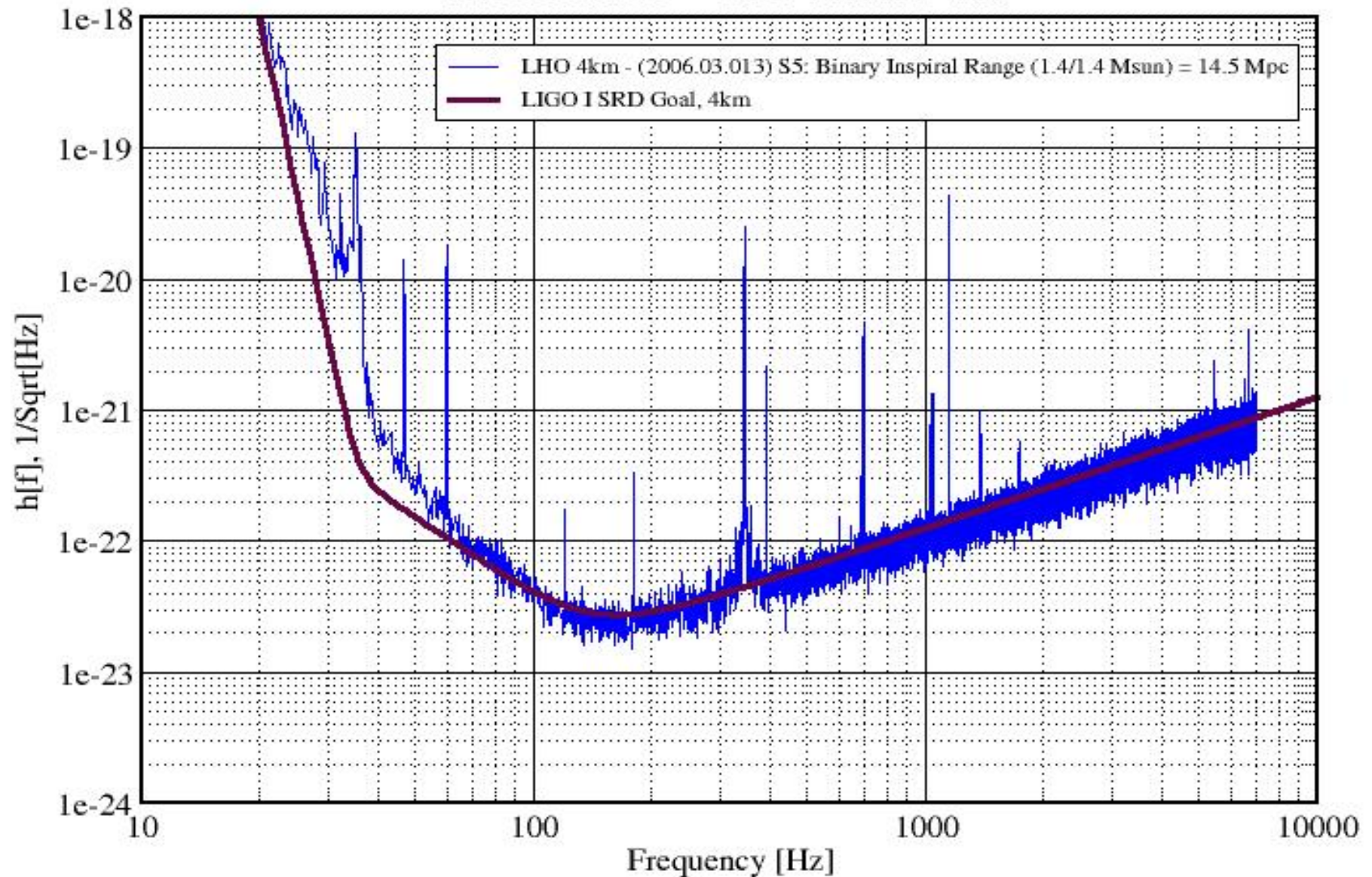
Summary curve deviation



Current S5 sensitivity

Strain Sensitivity for the LIGO Hanford 4km Interferometer

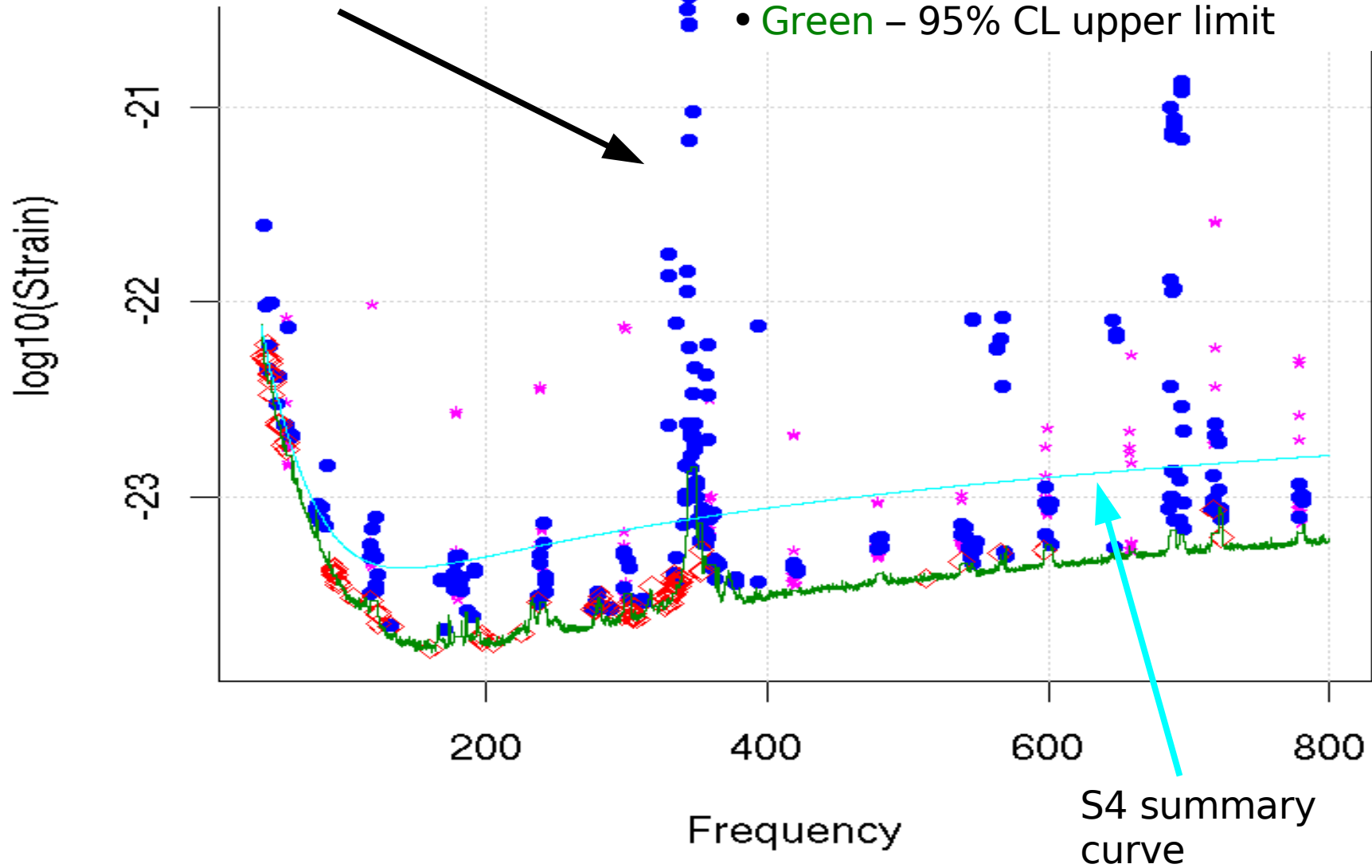
S5 Performance LIGO-G060051-00-Z



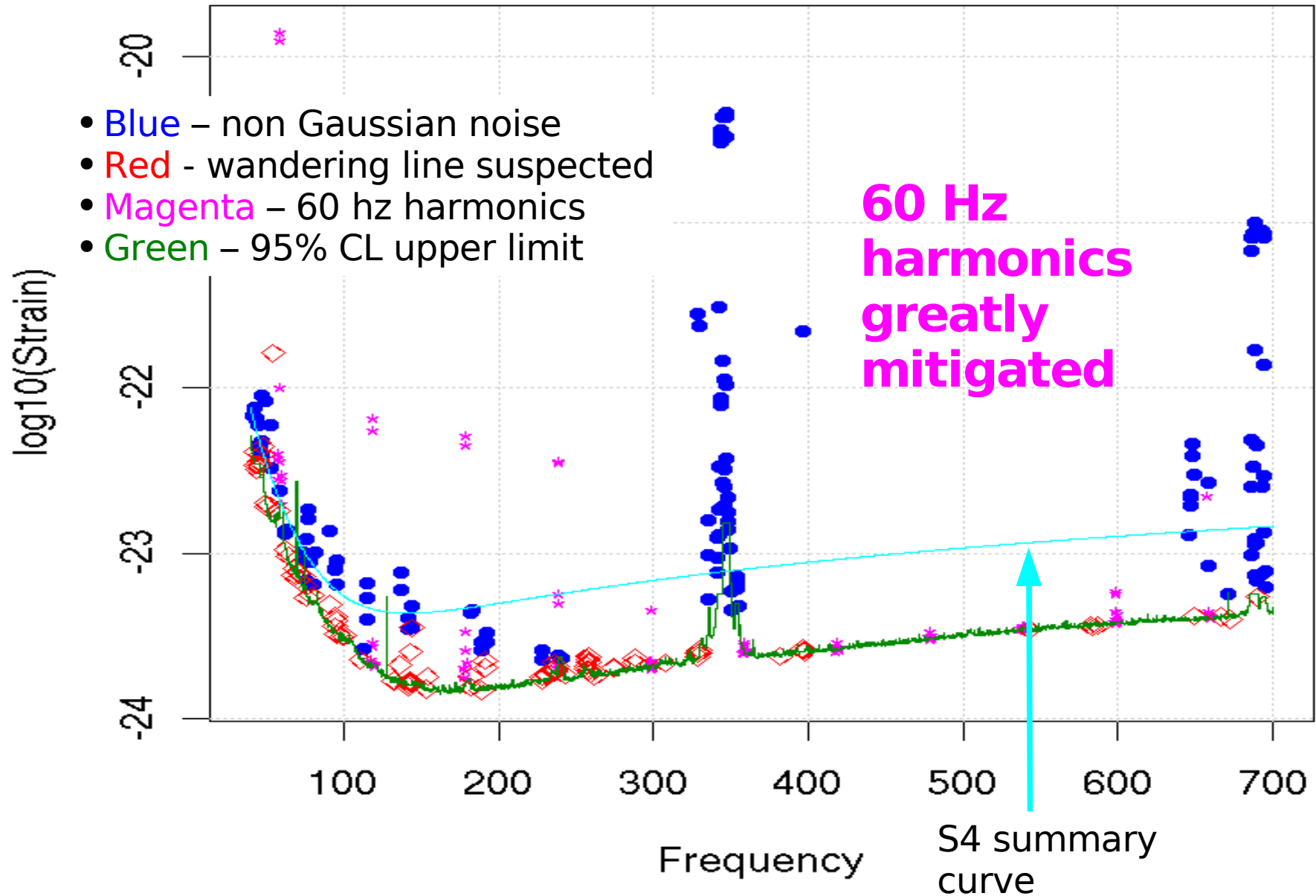
Early S5 Hanford 4km Preliminary Results 40-800 Hz (spindown 0)

Violin modes – from steel wires that support mirrors

- Blue – non Gaussian noise
- Red - wandering line suspected
- Magenta – 60 hz harmonics
- Green – 95% CL upper limit



Early S5 Livingston 4km Preliminary Results 40-700 Hz (spindown 0)



Conclusion

- Low-SNR coincidence algorithm under development
- S5 run is still underway – more data is being collected