LIGO

Broadband Search for Continuous-Wave Gravitational Radiation with LIGO

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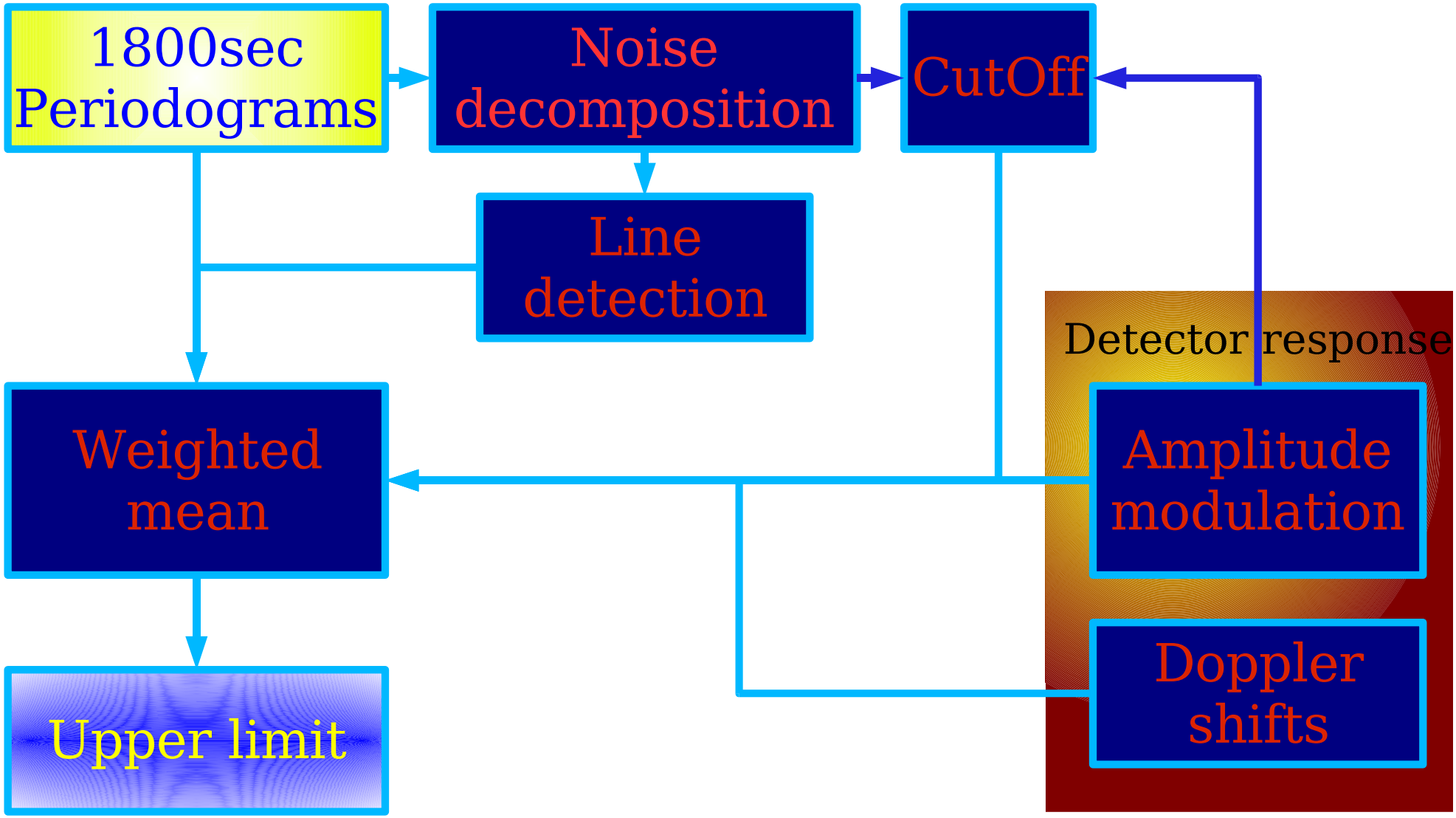
Challenges of search for CW gravitational waves

- Gravitational waves from spinning neutron stars are expected to be 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.

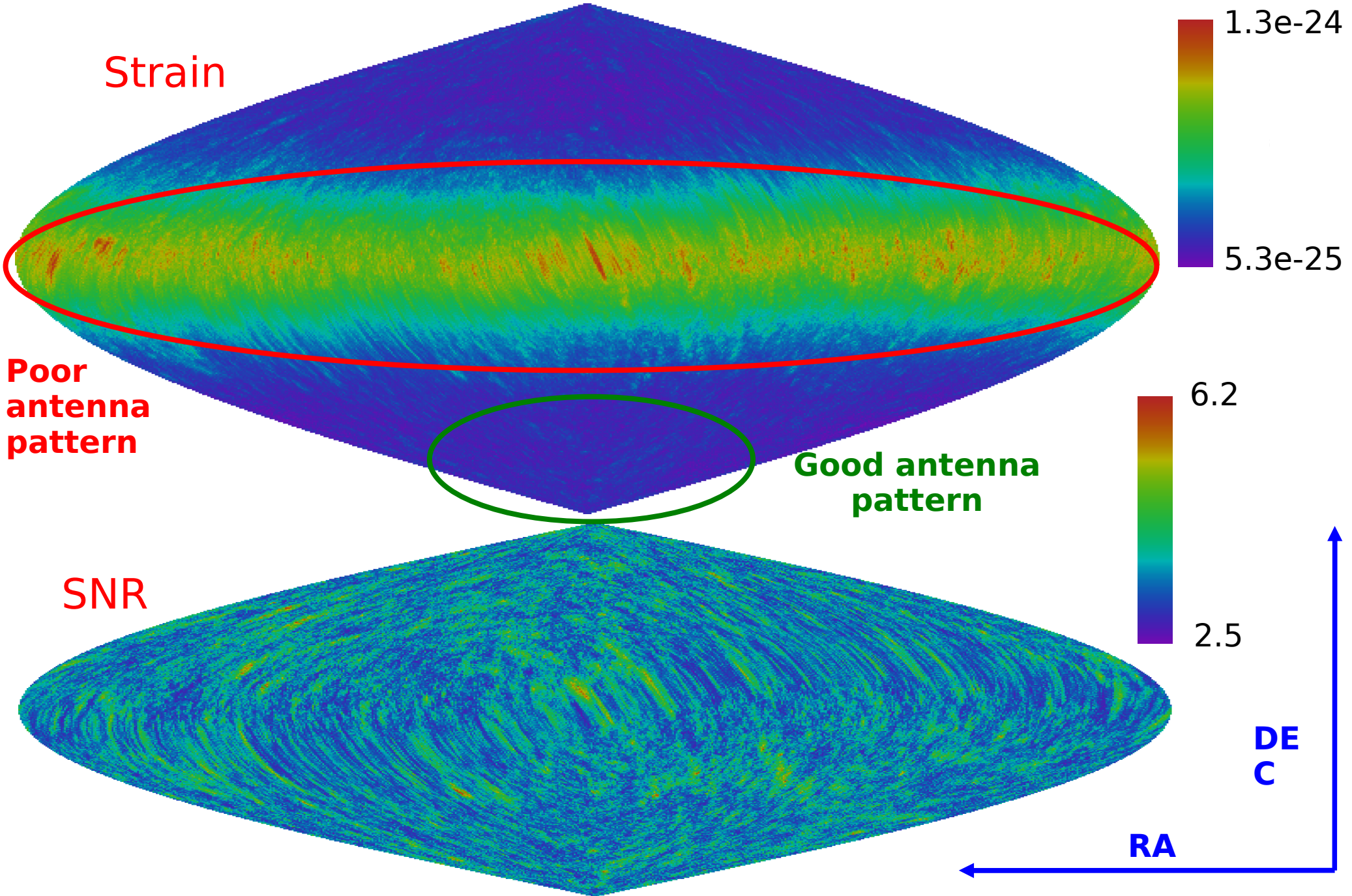
PowerFlux analysis pipeline



PowerFlux results

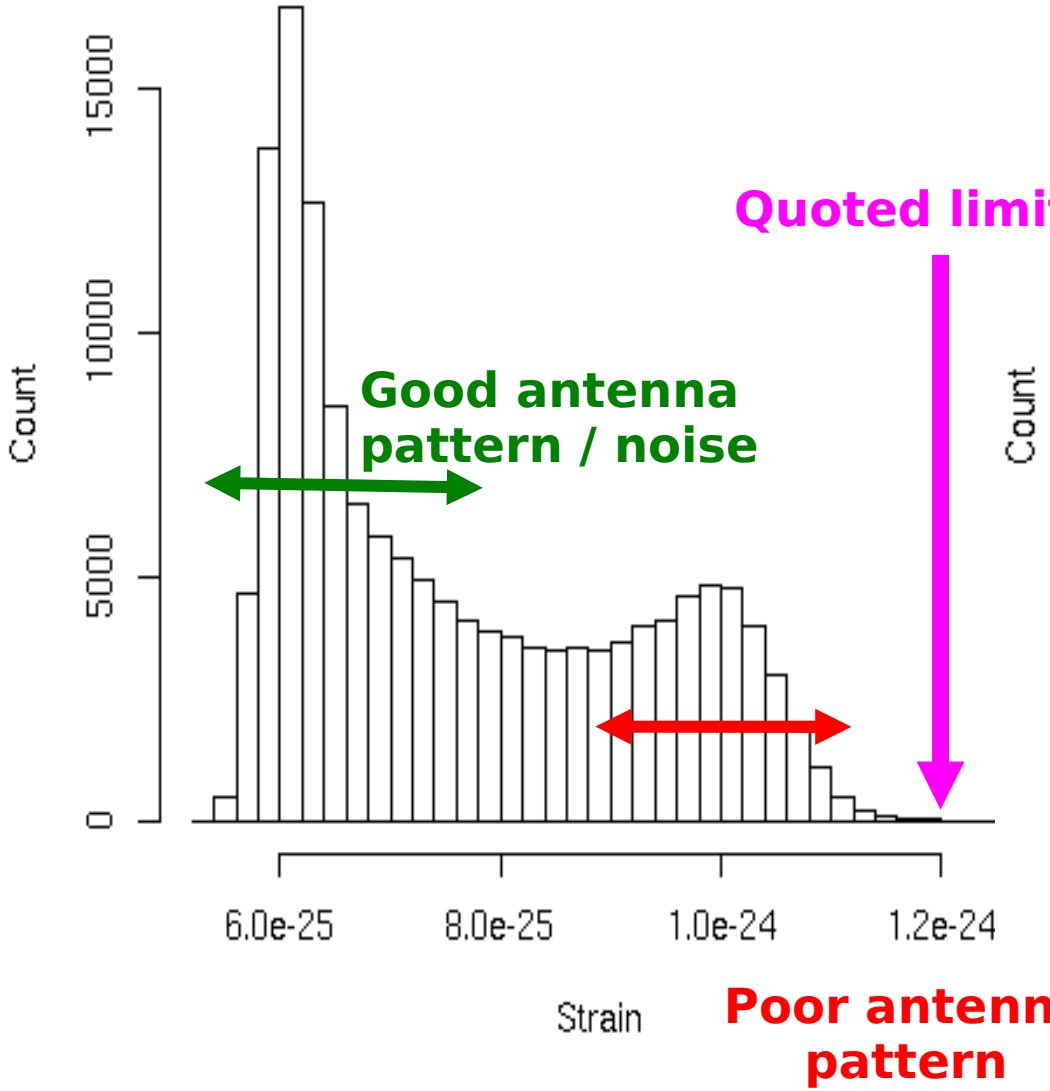
- PowerFlux produces a 95% CL upper limit for a particular frequency, sky position, spindown and polarization. One of three methods used in S4 all-sky search (arXiv:0708.3818 = to appear in Phys Rev D)
- Too much data to store, let alone present – the number of sky positions alone is ~10^5 at low frequencies and grows quadratically with frequency
- The upper limit plots show maximum over spindown range, sky and all polarizations
- Performed all-sky, multiple spindown searches
- Data from S5 science run: 7 Nov 2005 through 20 July 2006

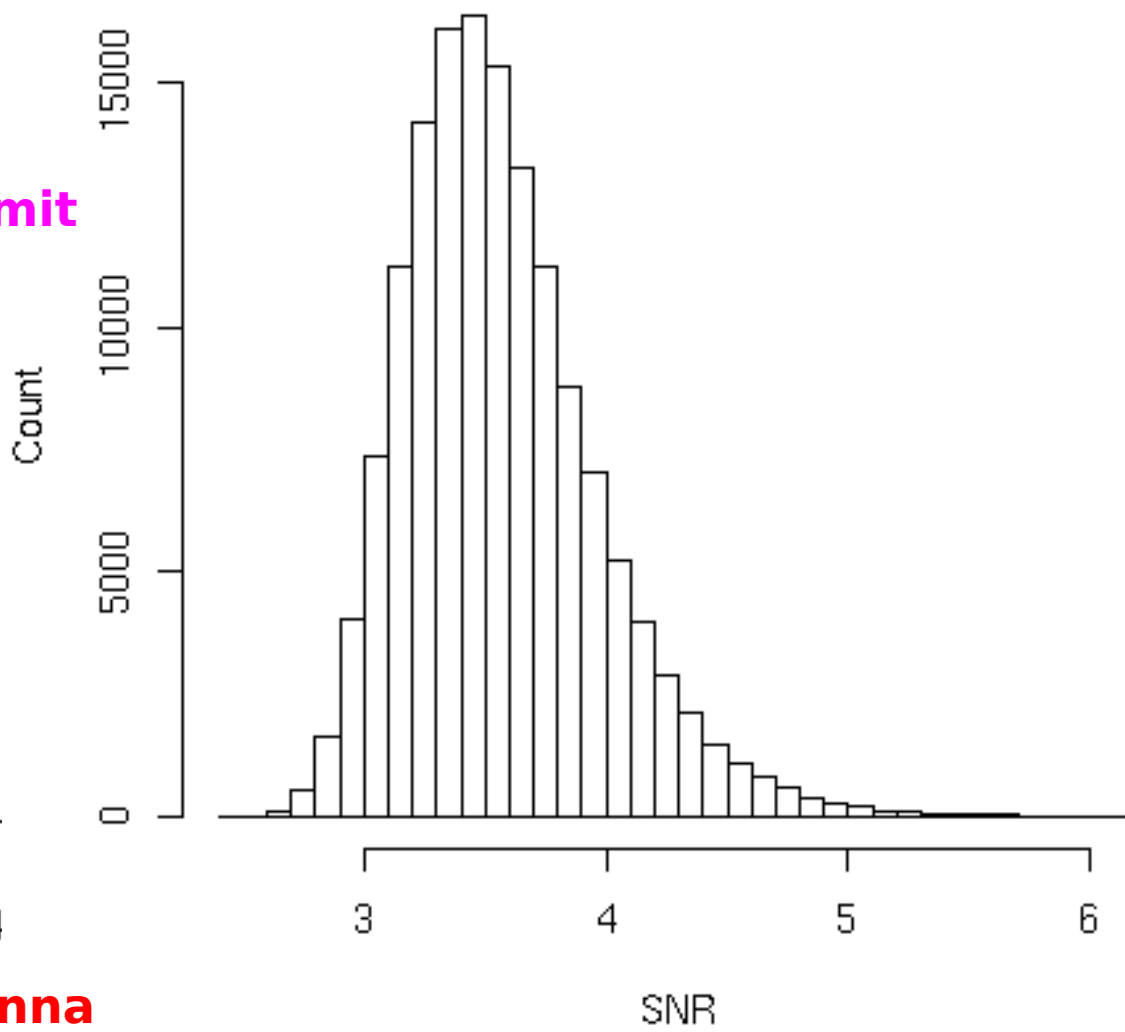
Hanford 4km, ~270 Hz, non-zero spindown
(equatorial coordinates)



Histograms

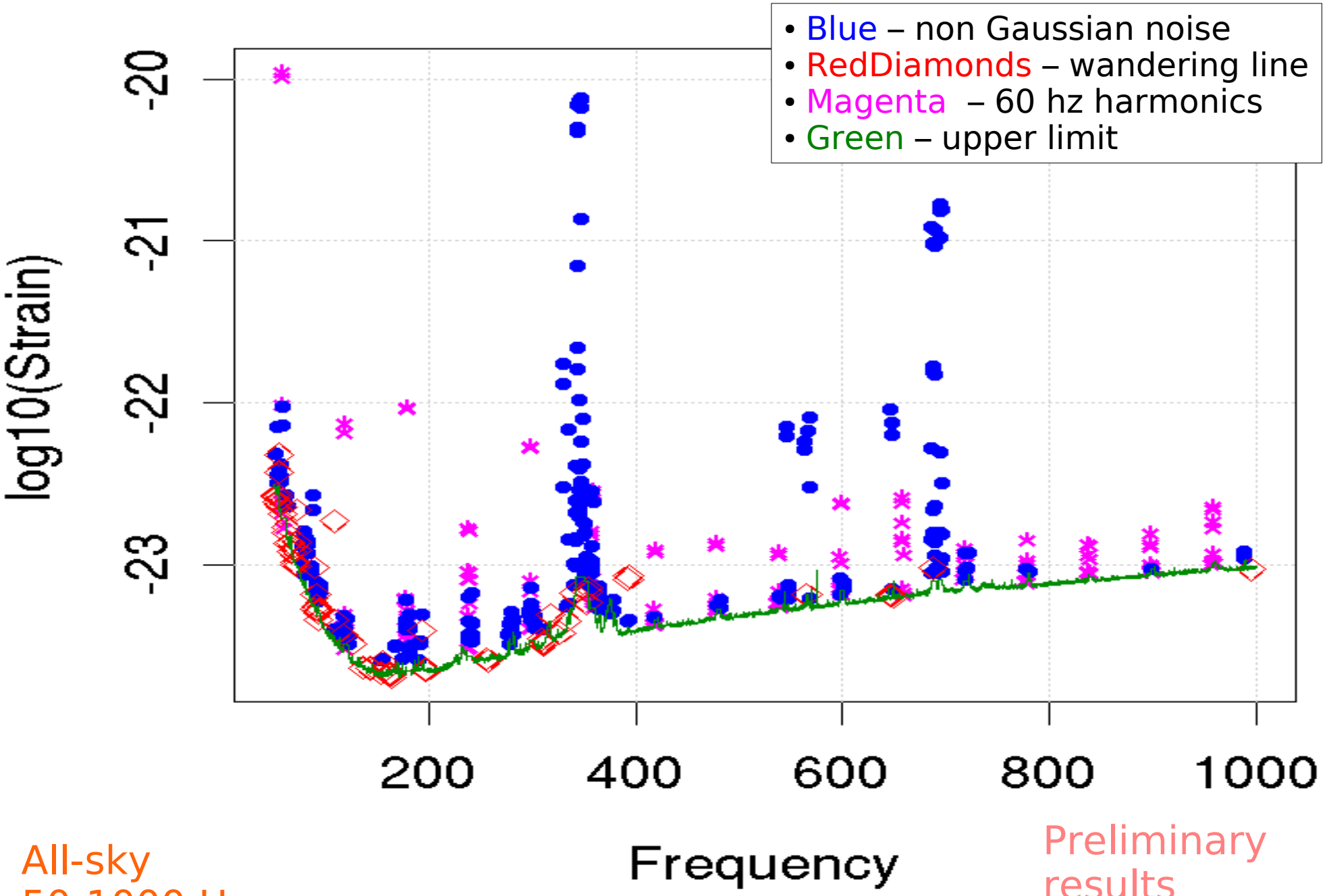
(one entry per sky point)





Preliminary results

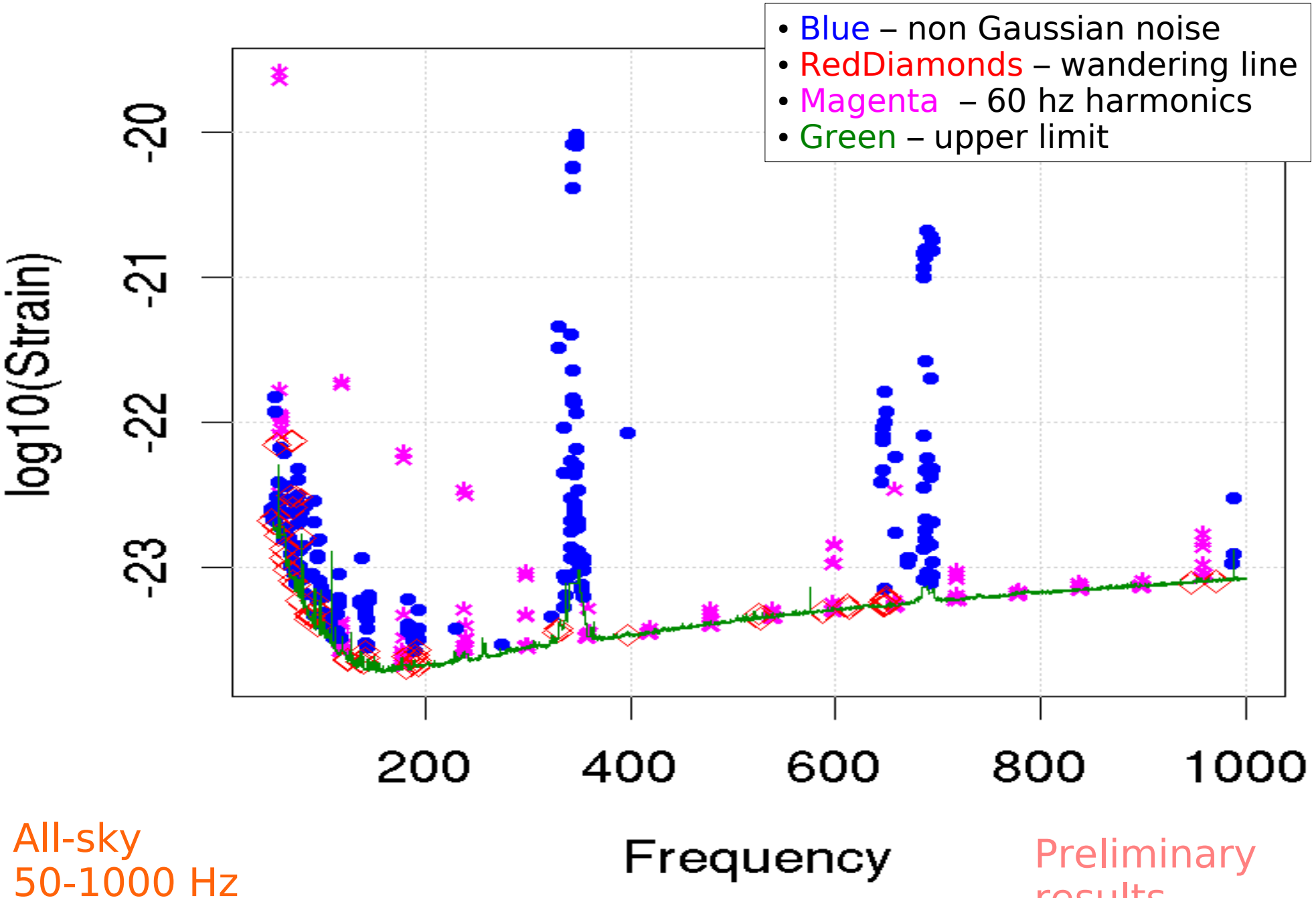
H1 S5 0-spindown run



All-sky
50-1000 Hz

Preliminary
results

L1 S5 0-spindown run



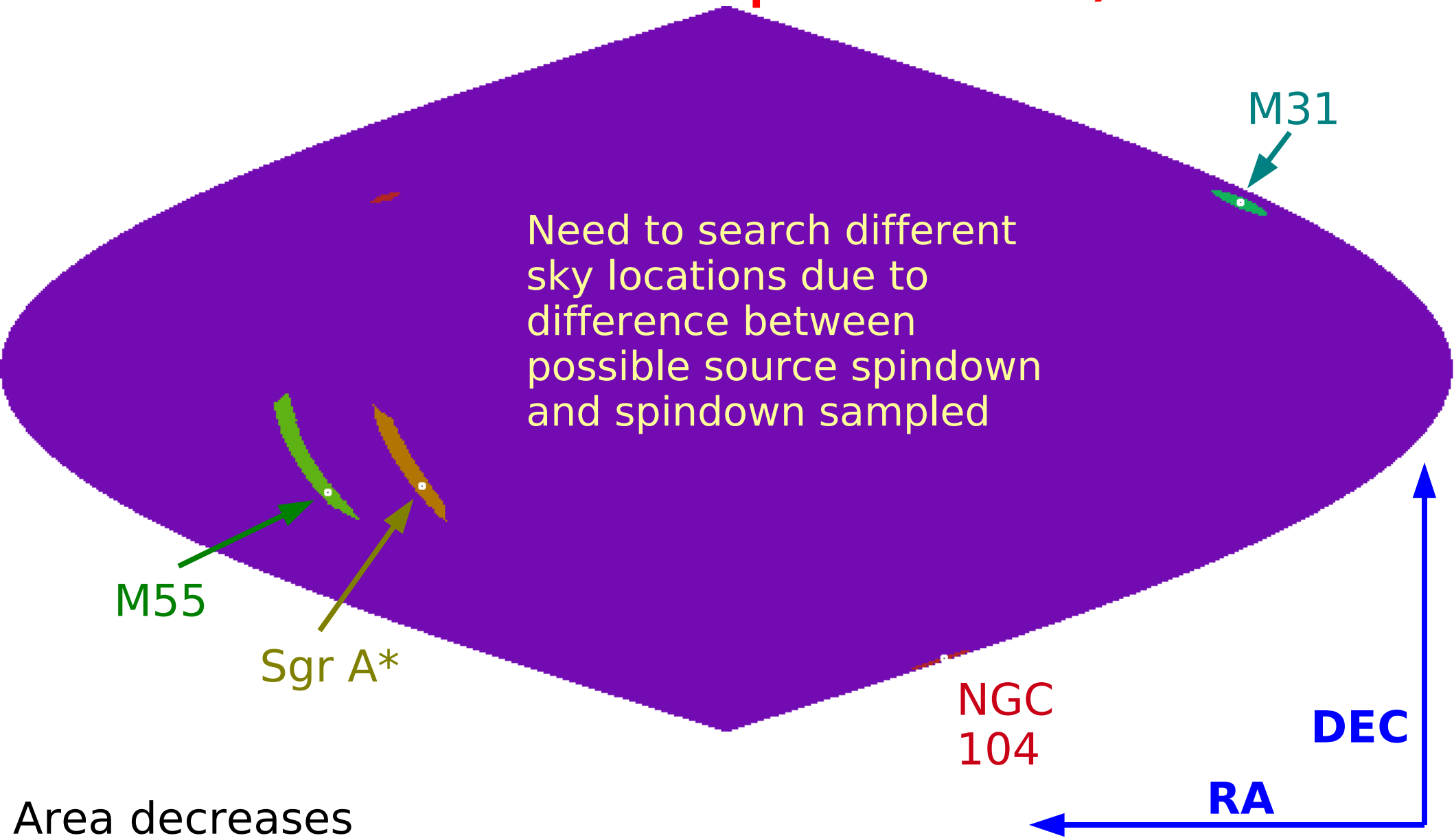
All-sky
50-1000 Hz

Preliminary
results

Partial sky (targeted) run

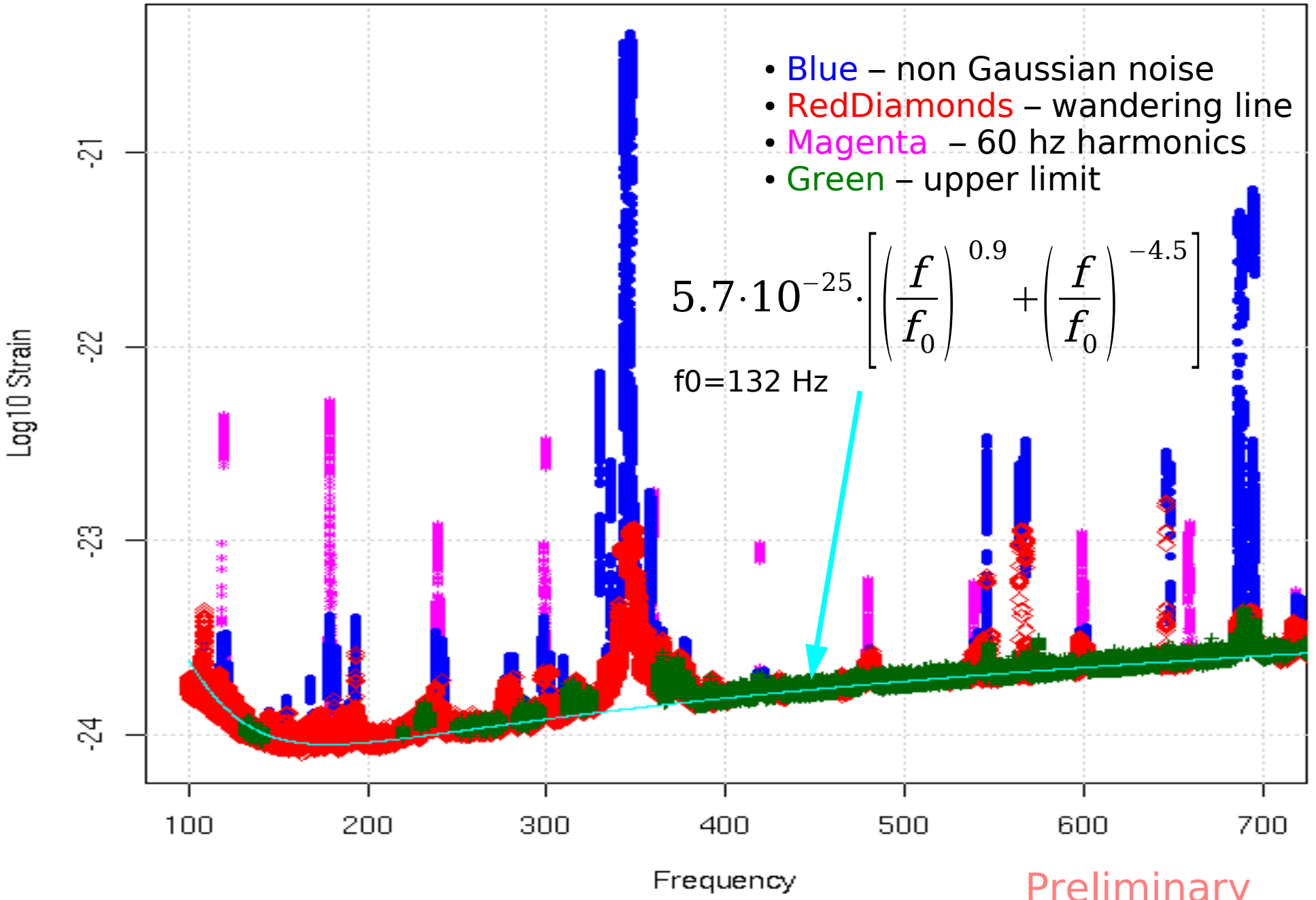
- Searched sky around
  - globular clusters M55, NGC104
  - galactic center Sgr A*
  - Andromeda M31 (control)
- 100-700 Hz
- -1.01e-8 Hz/s through 1.01e-8 Hz/s in 2e-10 Hz/s steps

Search area (for ~270 Hz, non-zero spindown)



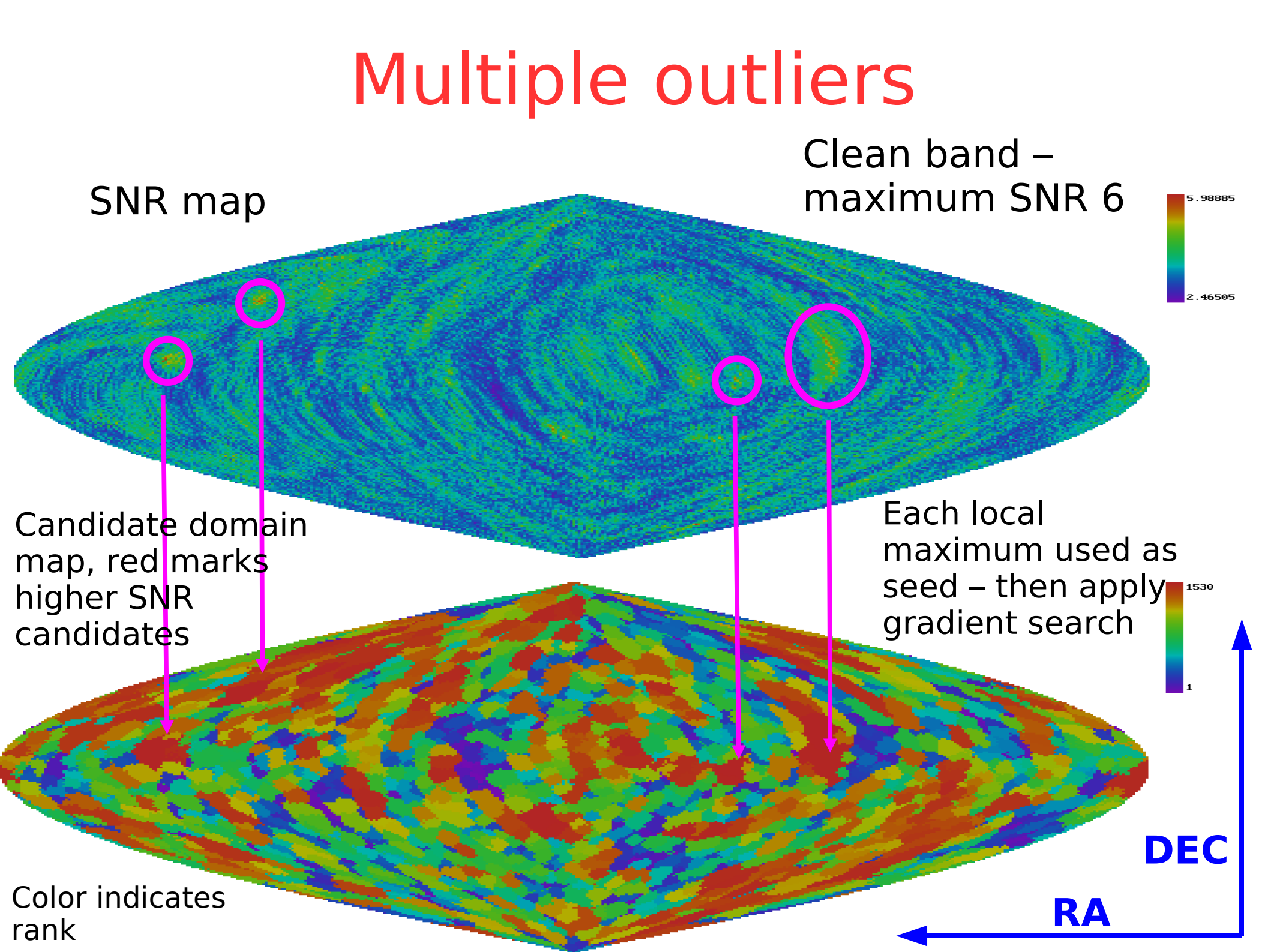
Area decreases with frequency

H1 Sgr A* upper limits



Preliminary results

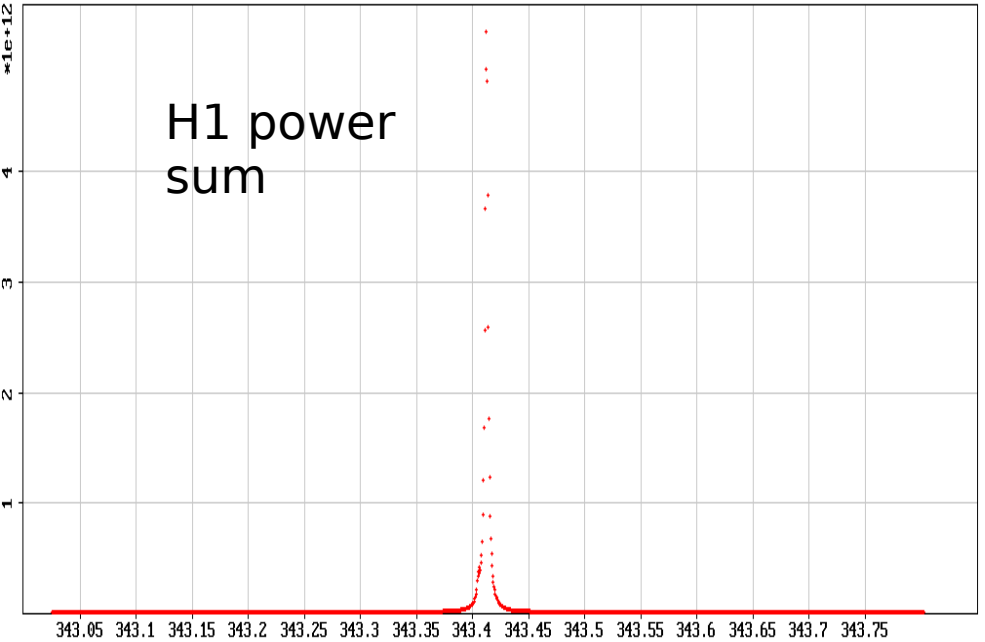
Multiple outliers

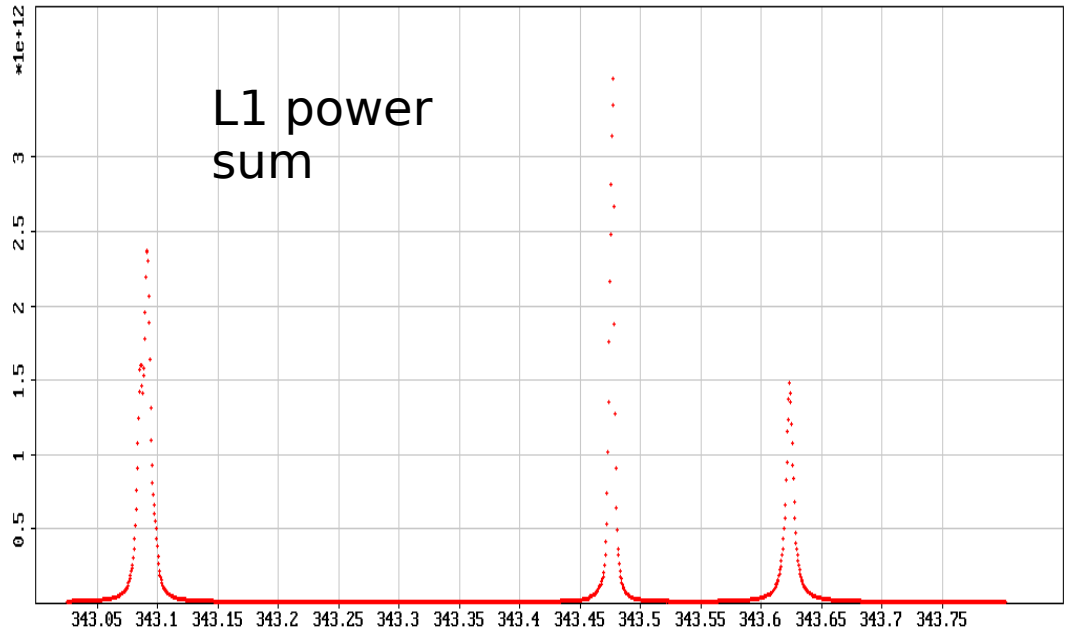


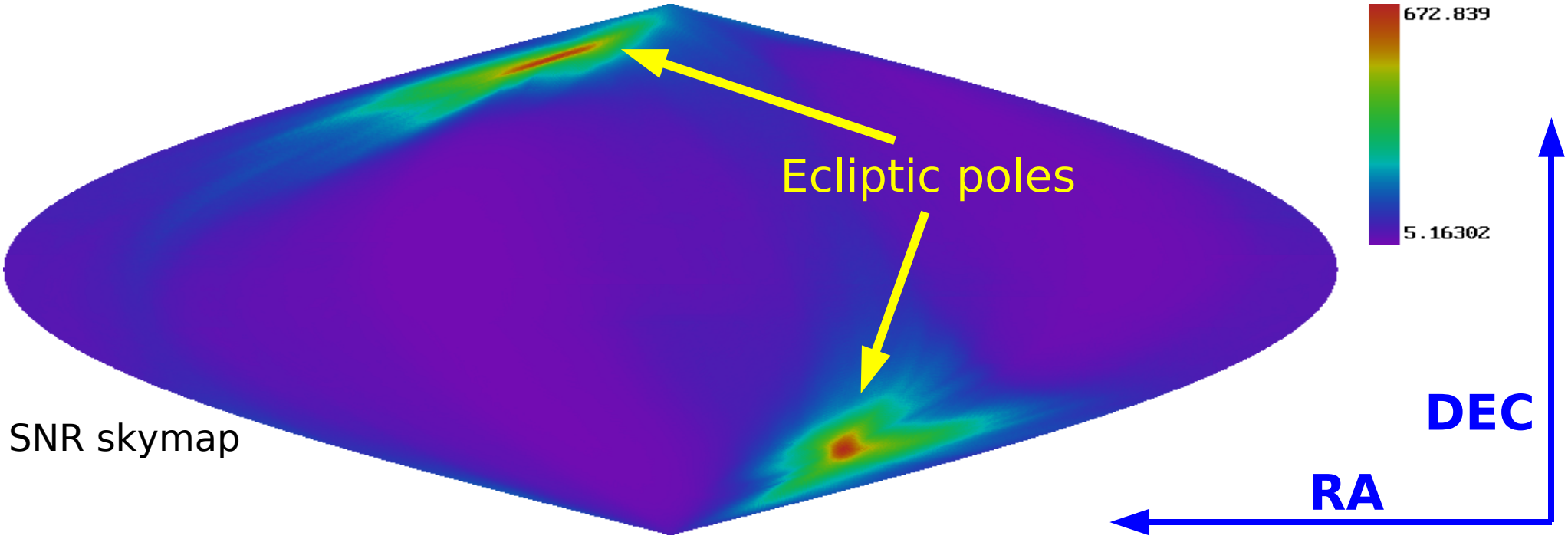
Outlier followup

- Determine local SNR maxima, pick N highest (1000-10000)
- Apply a variation of gradient search to optimize SNR and narrow down frequency, spindown, sky location and orientation
- Look for outliers common to two interferometers:
  - SNR>6.0 for each interferometer
  - Difference in frequency less than 1/180 Hz
  - Difference in spindown of less than 4e-10 Hz/s
  - Closer than 0.14 radians (~8 degrees) on the sky

Sample outlier - caused by violin modes (5)







SNR skymap

Issues in followup

- Number of sky positions comparable with quantity of input data (especially at high frequencies) – SNR of the loudest outlier in pure noise can easily reach 6.0
- Relatively loose coincidence requirements are necessary not to miss real signals
- Parameters that are narrow for a semi-coherent search are too wide for a comfortable coherent followup

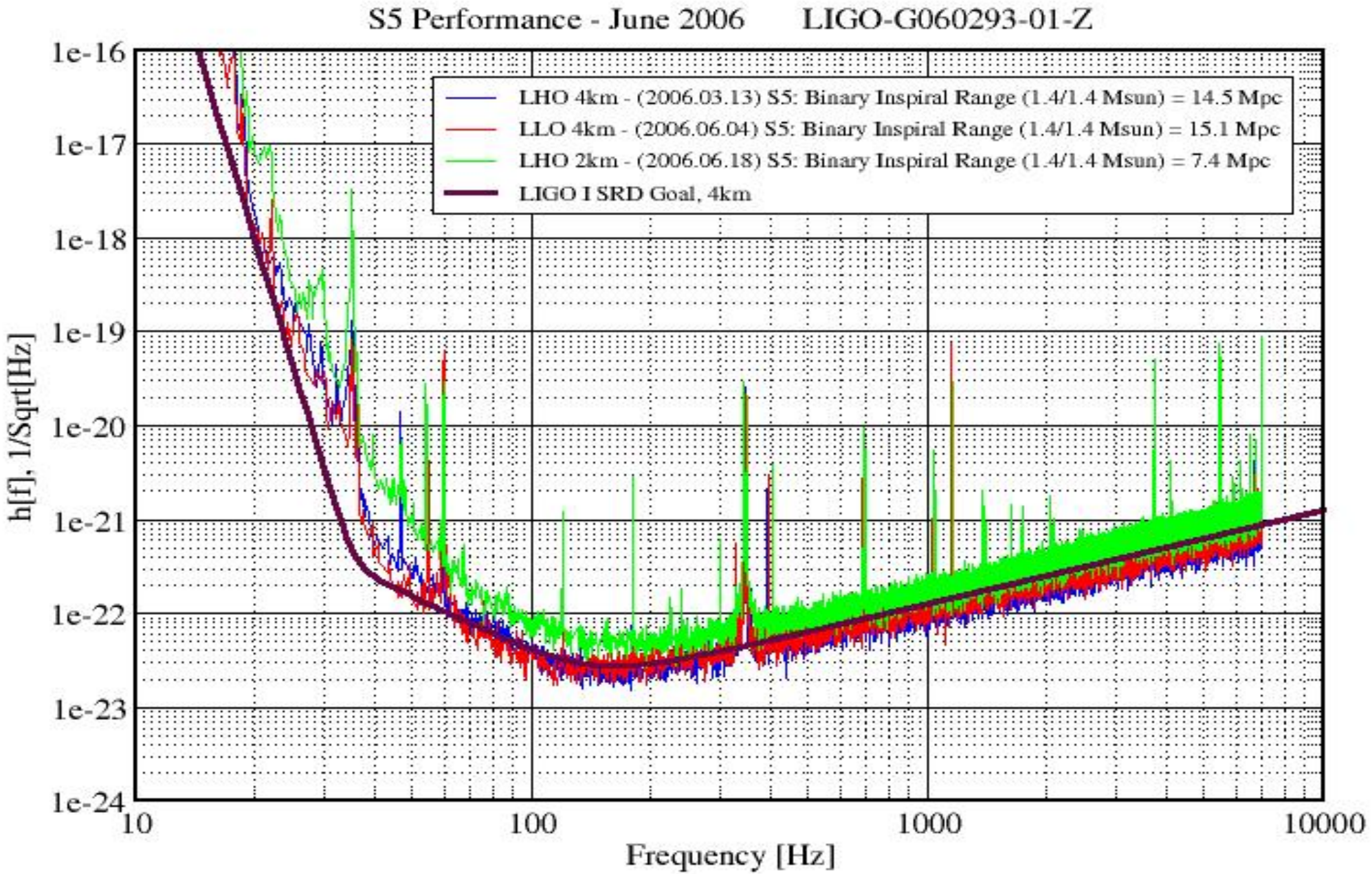
Conclusion

- All-sky multiple-spindown run over first 8 months of data complete, followup in progress
- Looking in detail at the output of low-SNR coincidence algorithm
- Full S5 data is available, more results to follow

End of talk

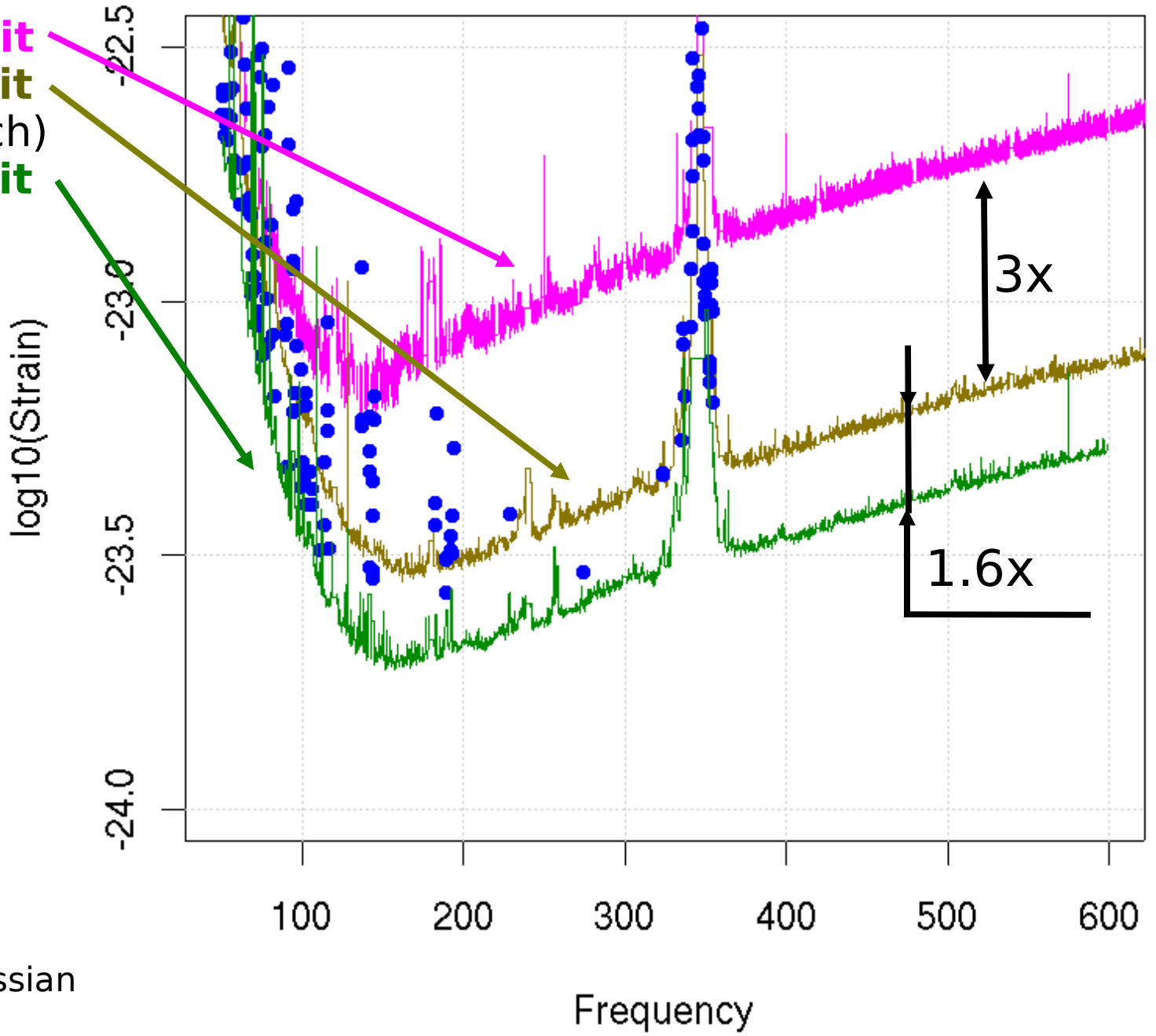
(supporting slides for questions follow)

S5 science run sensitivity



S5 spindown-0 run

- **S4 L1 upper limit**
- **S5 L1 upper limit**
(data through March)
- **S5 L1 upper limit**
(data through July)

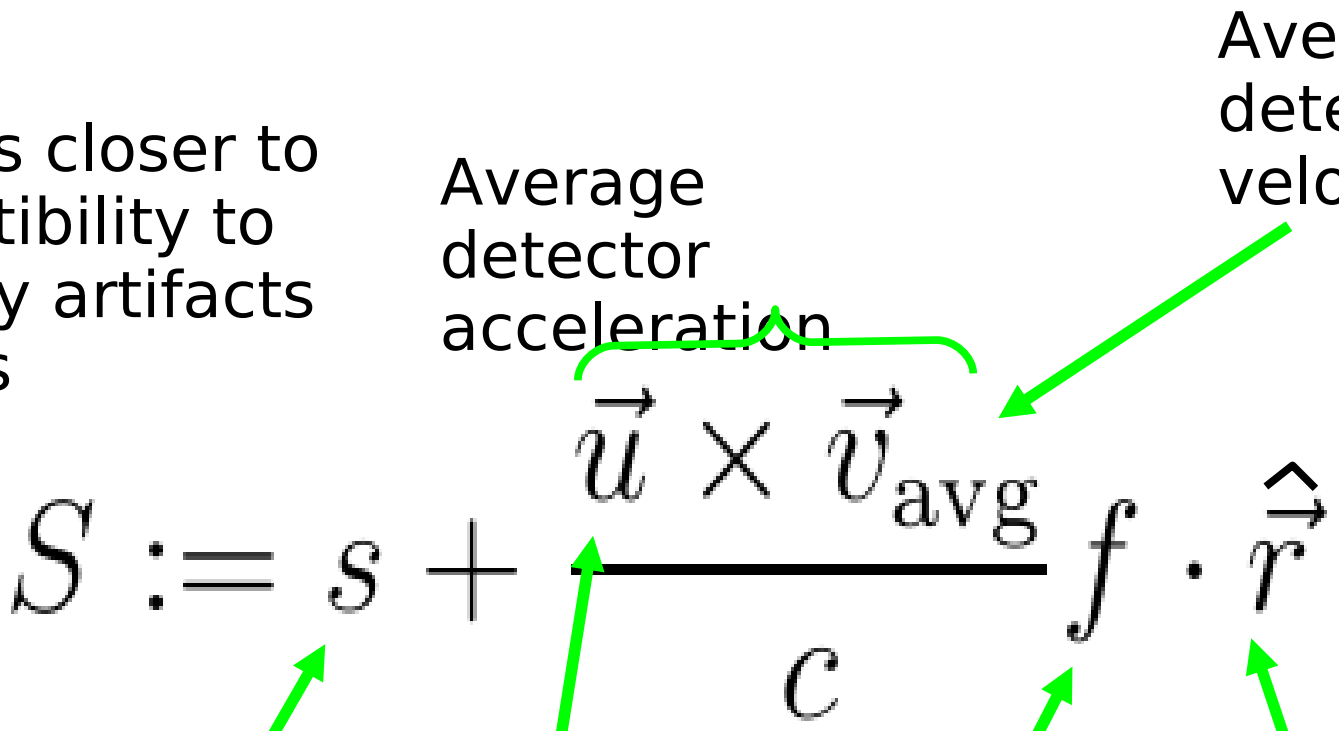


July L1 SFTs=
3x March SFTs

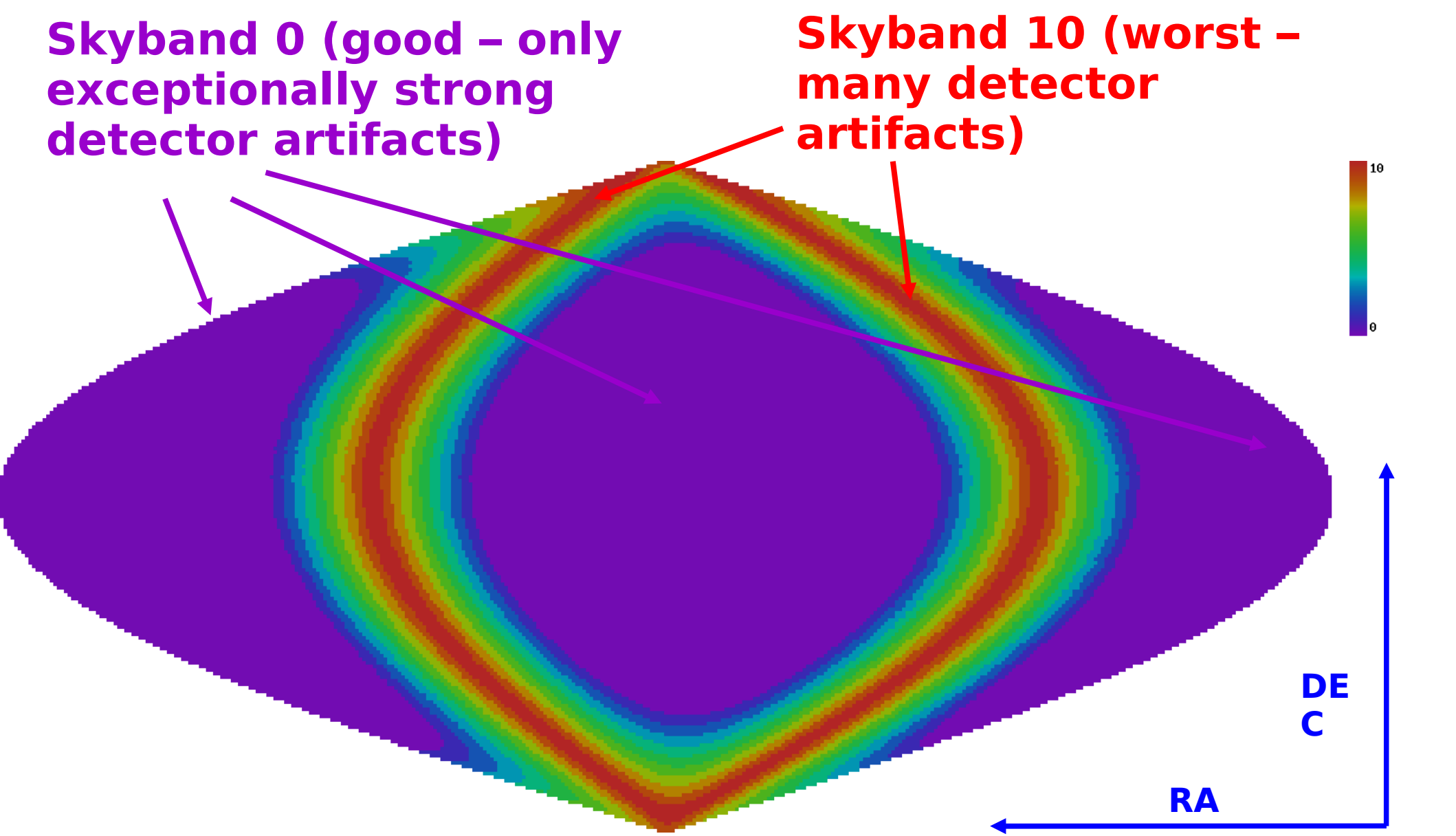
- 60 Hz lines excluded
- Blue points – non-gaussian noise in July run

“S parameter”

When S is closer to 0 susceptibility to stationary artifacts increases

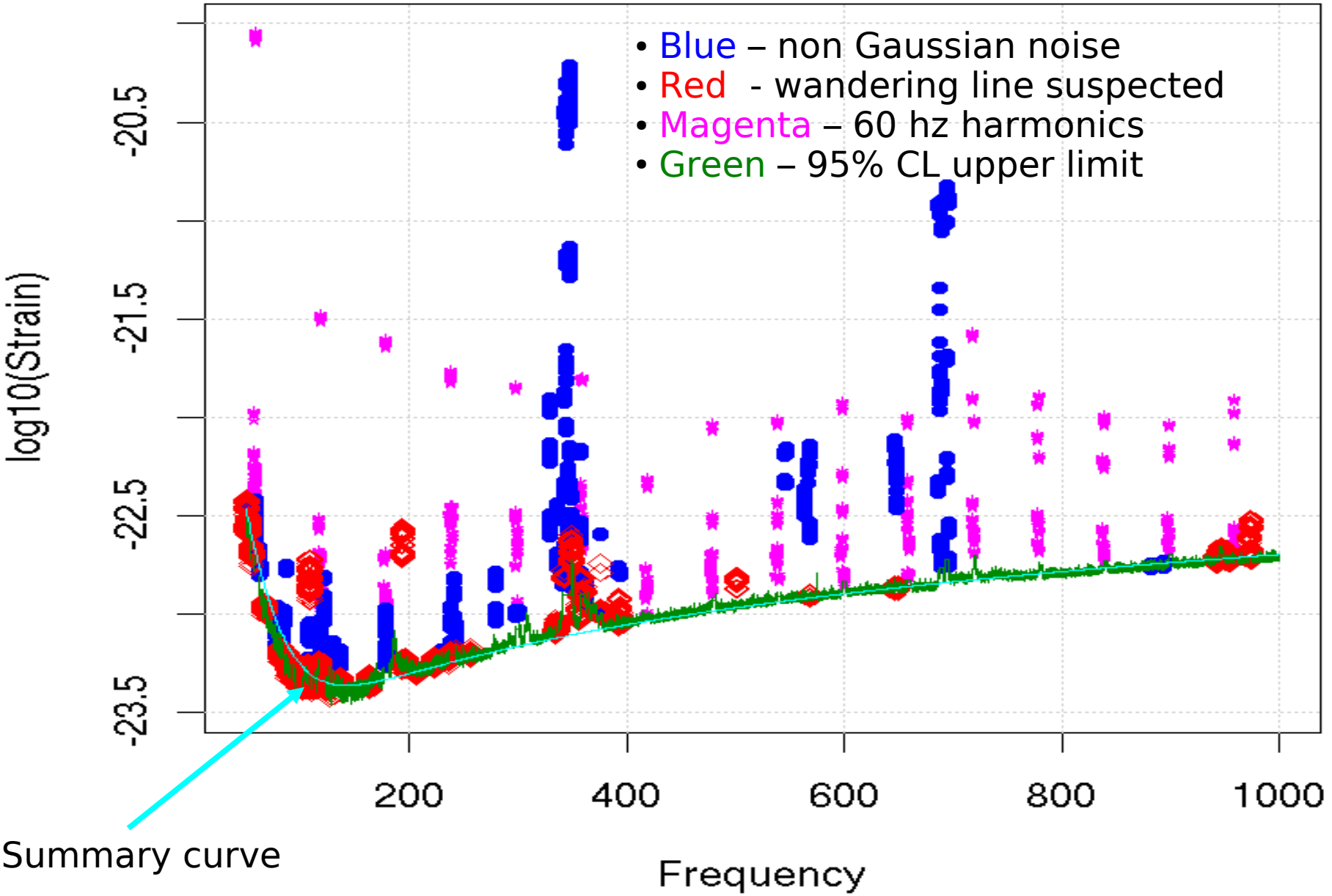


Doppler Skybands



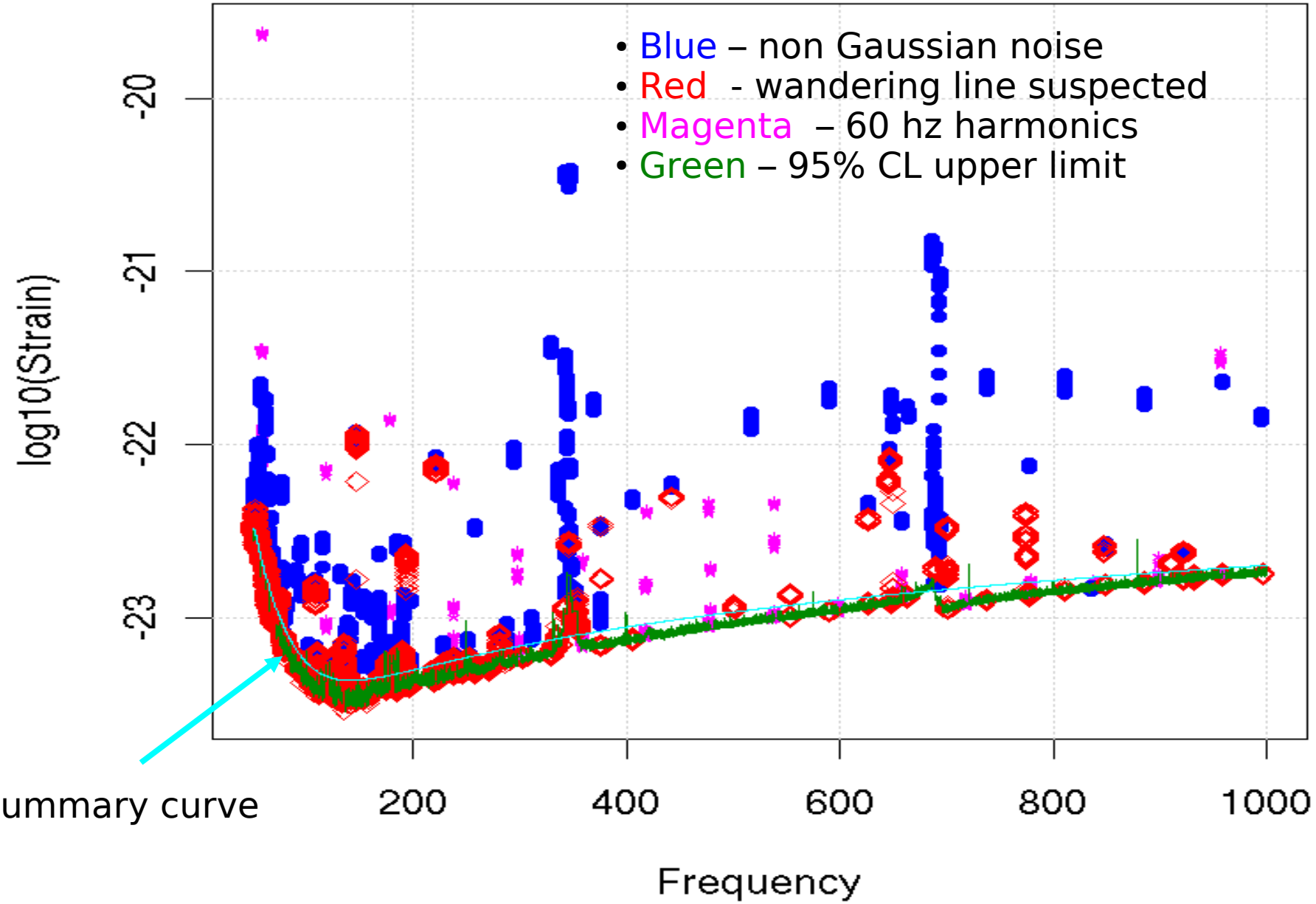
S4 run results
Hanford 4km

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



S4 run results
Livingston 4km

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



Summary curve

S5 summary curve deviation