Detecting global magnetic fields near Virgo

Melissa A. Guidry

Irene Fiori, Federico Paoletti

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Outline

1. Background
2. Quiet standard
   - Schumann resolution
   - Coherence analysis
3. On-site quiet installation
   - Sites tested
   - Schumann resolution
   - Sideband noise

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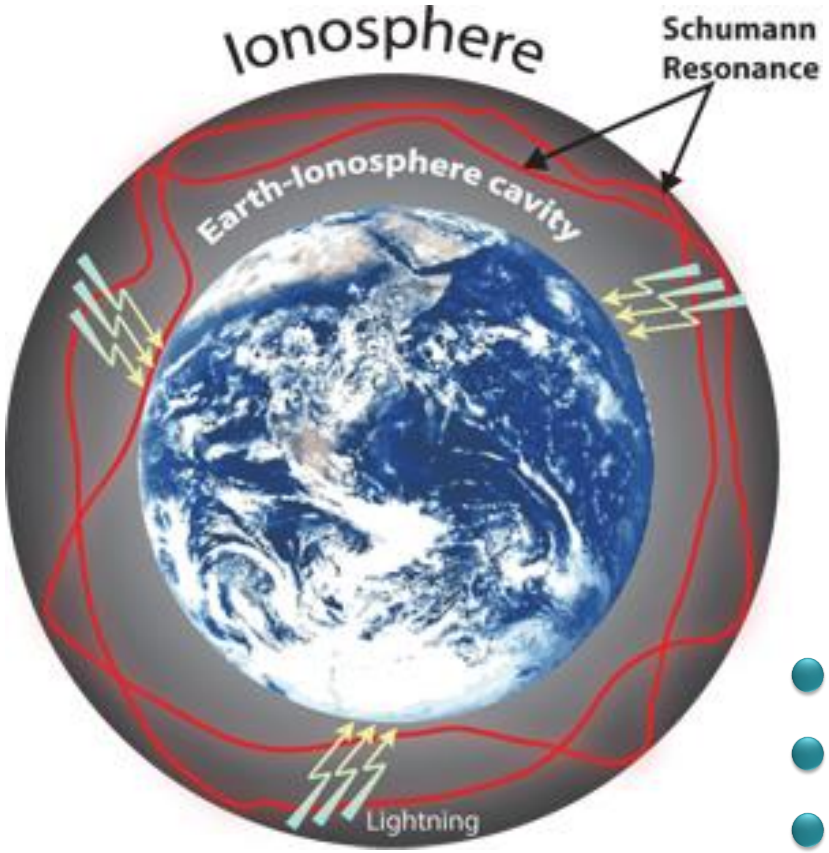
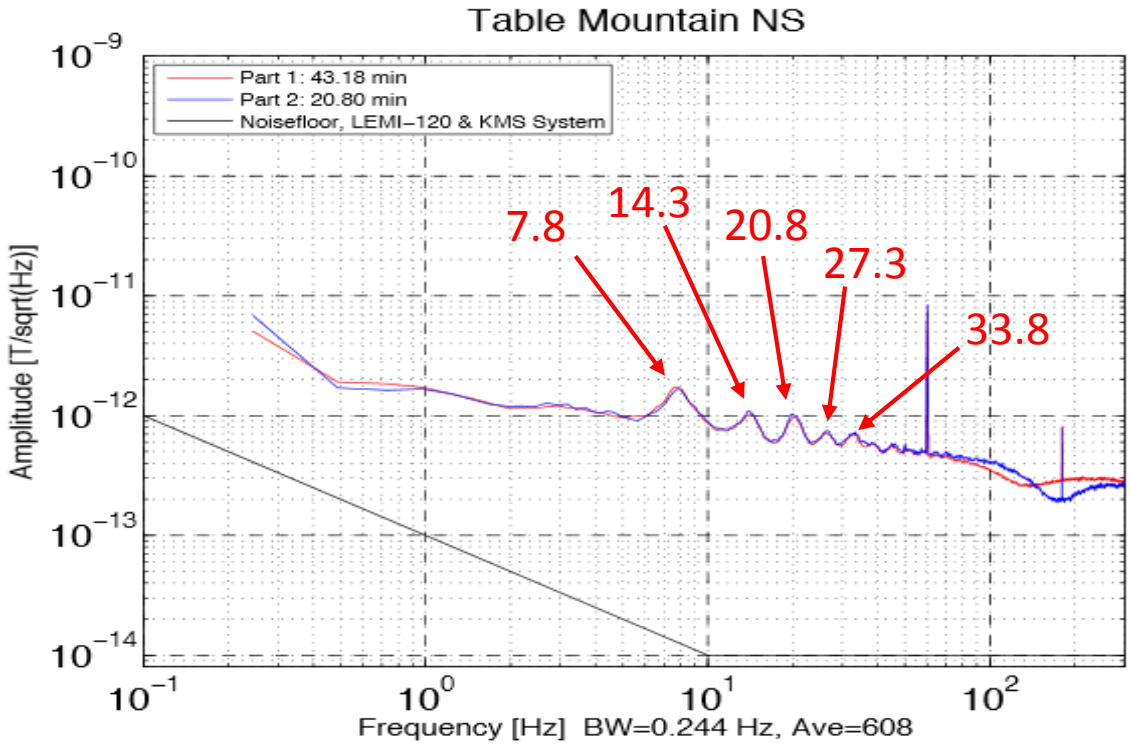
Schumann resonances

Global EM resonances



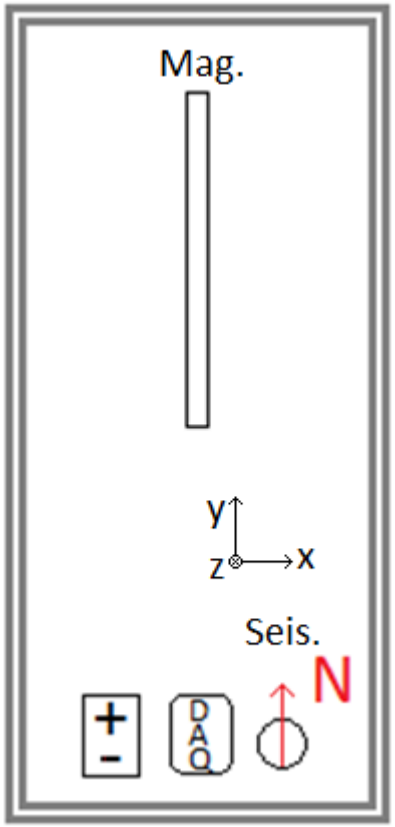


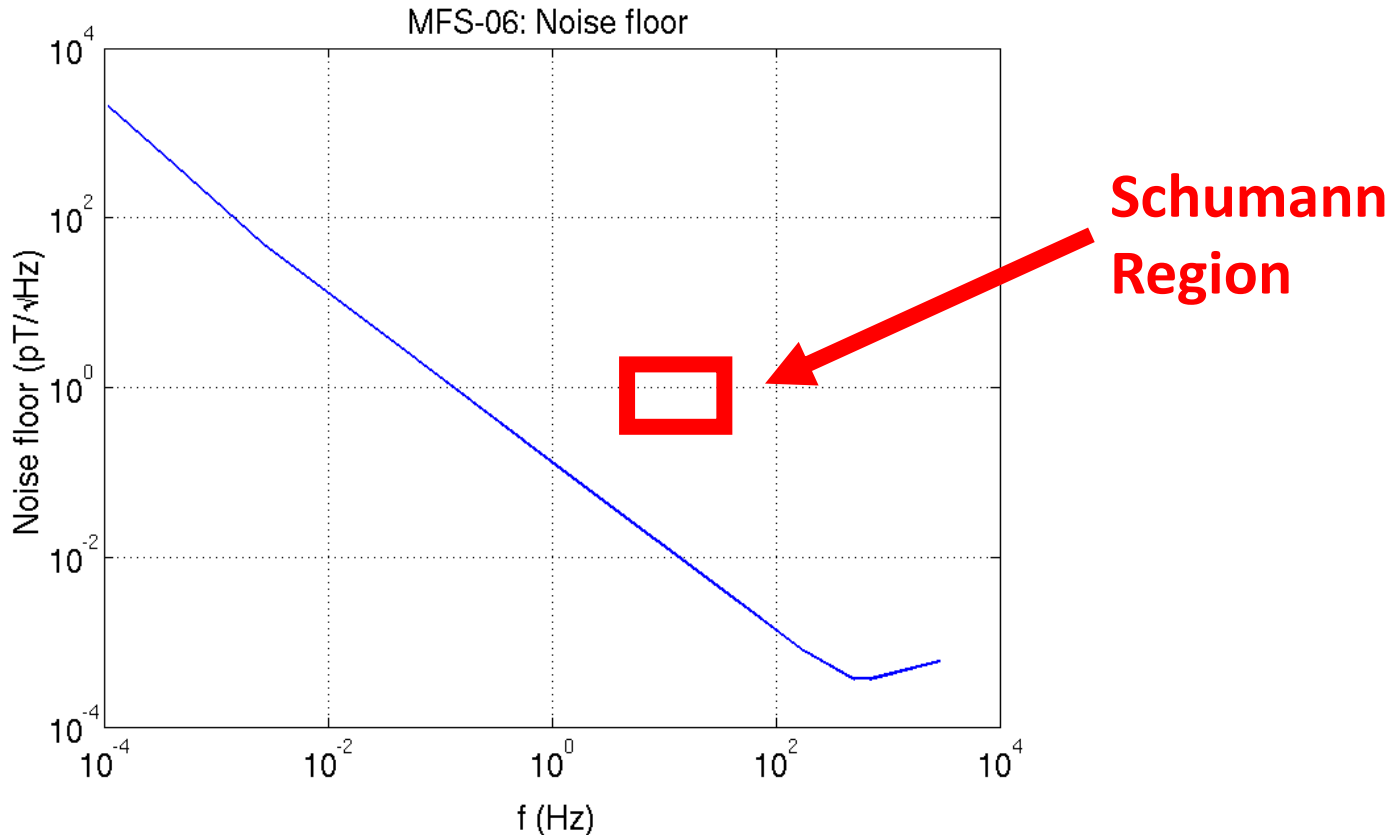
[aLIGO LHO Logbook Entry **12525**, Schofield et al.]

- ~100 lightning strikes/sec
- $0.5 - 1.0\ pT/Hz^{1/2}$
- $10\ pT$ bursts above $1\ pT$ background at $0.5\ Hz$ rate

Procedure

- MFS-06 magnetometer
- Centaur 24-bit digitizer
- 12 V battery
- Trillium three-axis seismometer
- 16 GB memory card
- DC-to-DC converter box

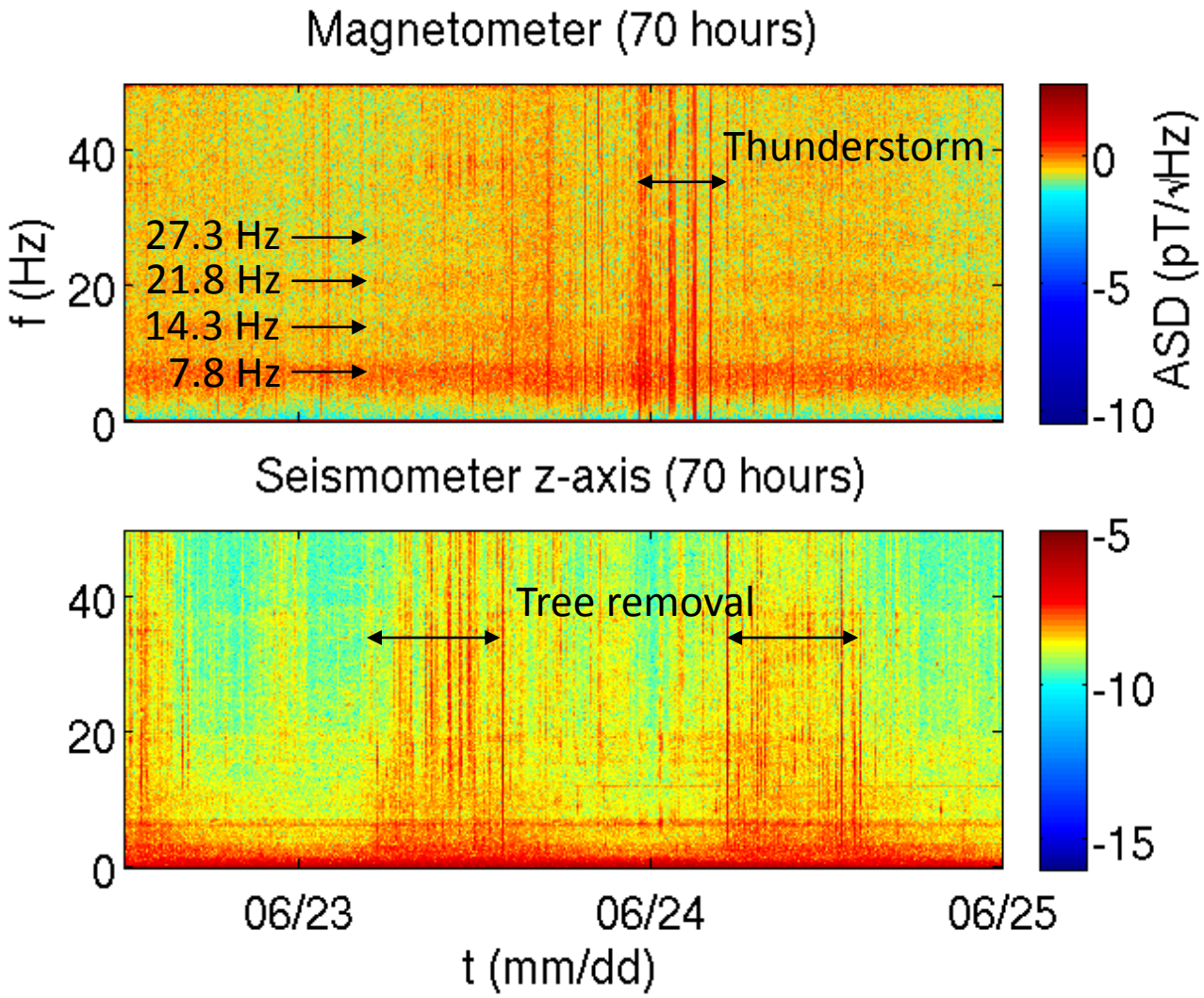




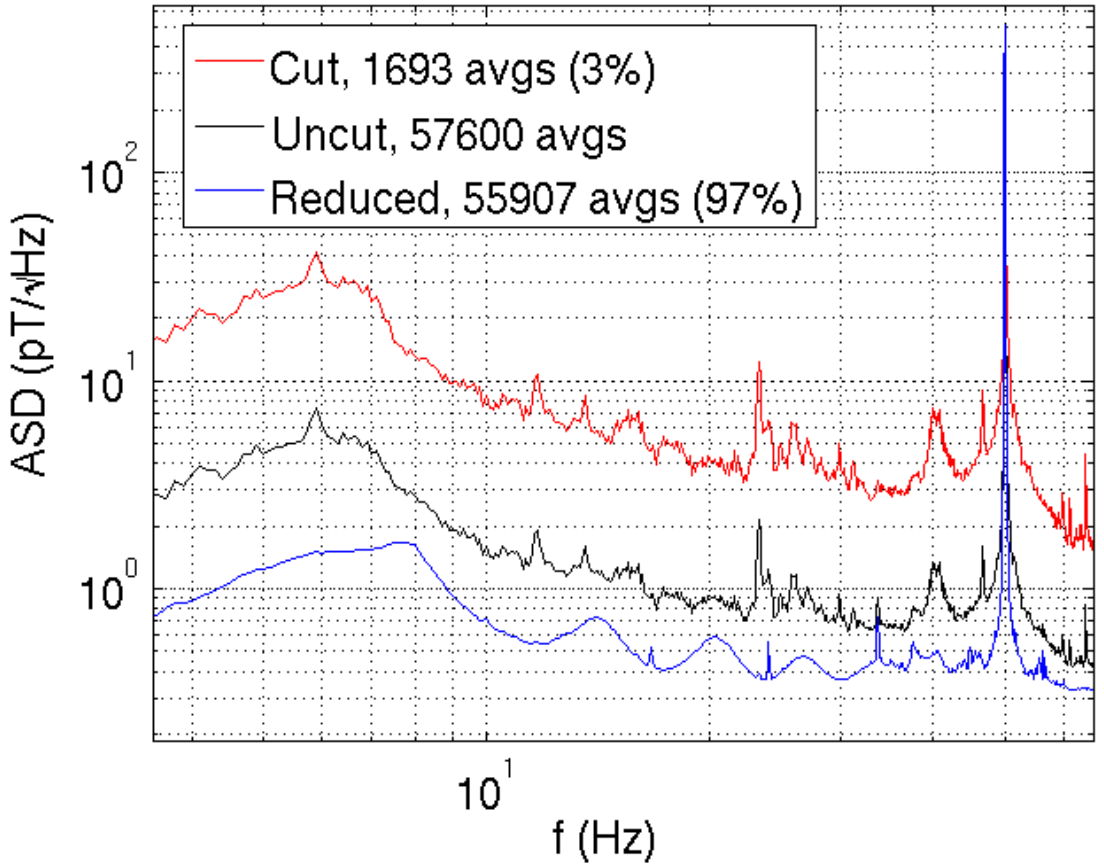
Quiet standard: Villa Cristina

- Livorno Hills scout house
  - 13 km South-West of Virgo
- Mag. axis North-South
- DAQ ~4 m away
- June 22-25, 29-July 3 (160 hours)

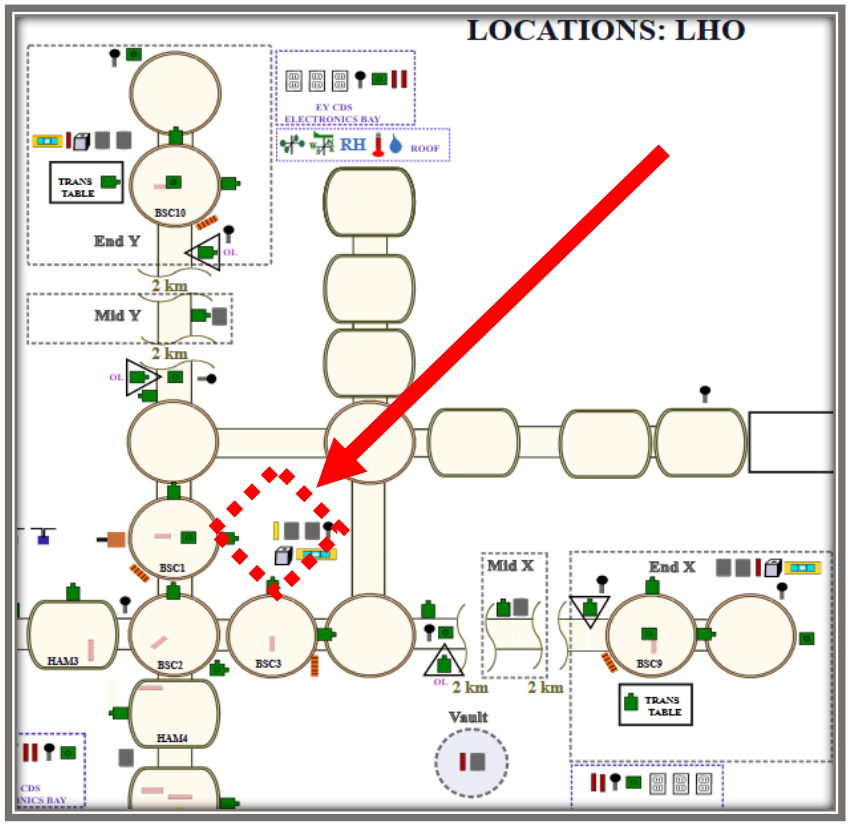
Villa Cristina: Schumann resolution

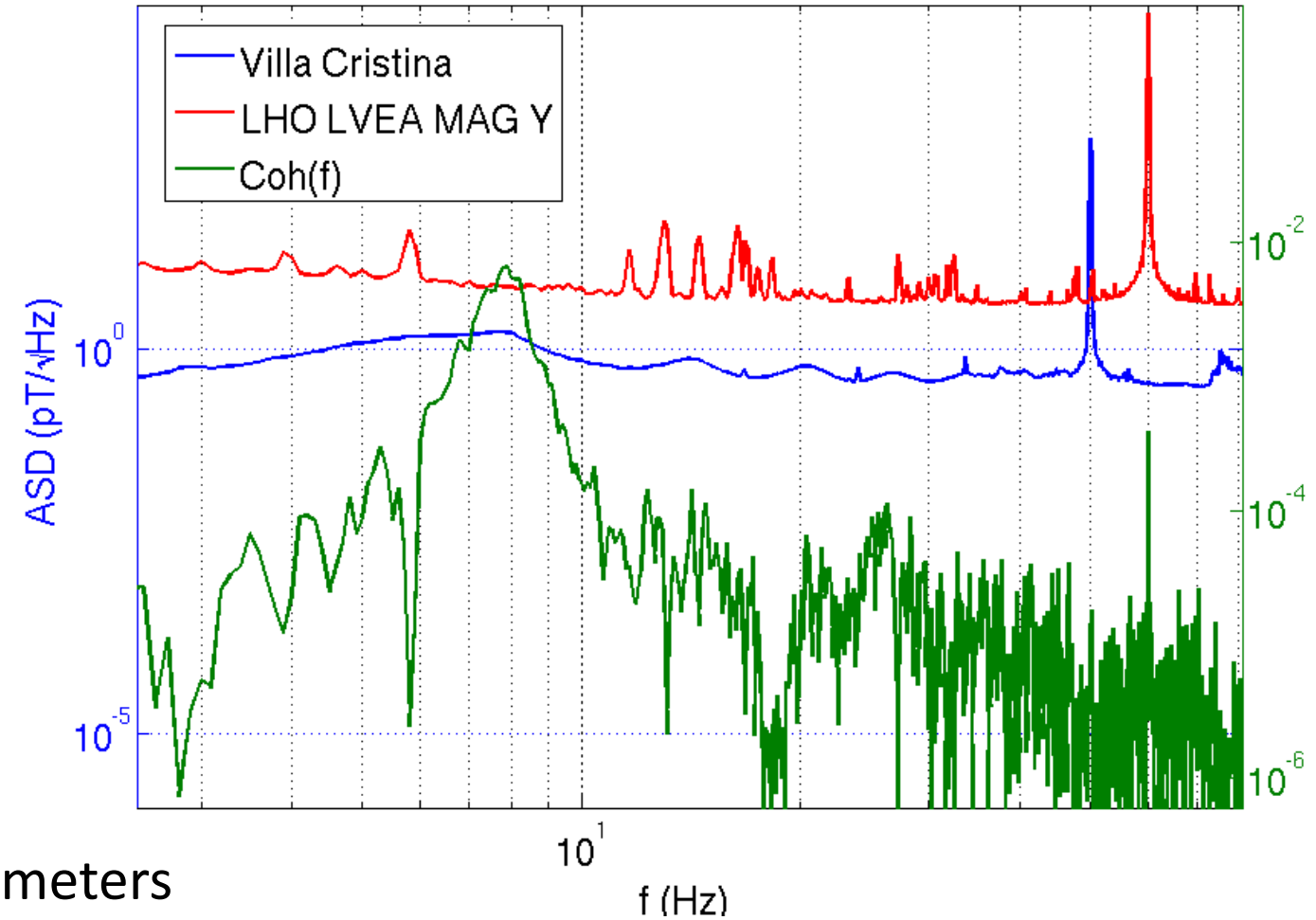


- Threshold: 10-30 Hz full-spectrum ASD avg.
  - Remove spectra above threshold



Villa Cristina: Coherence





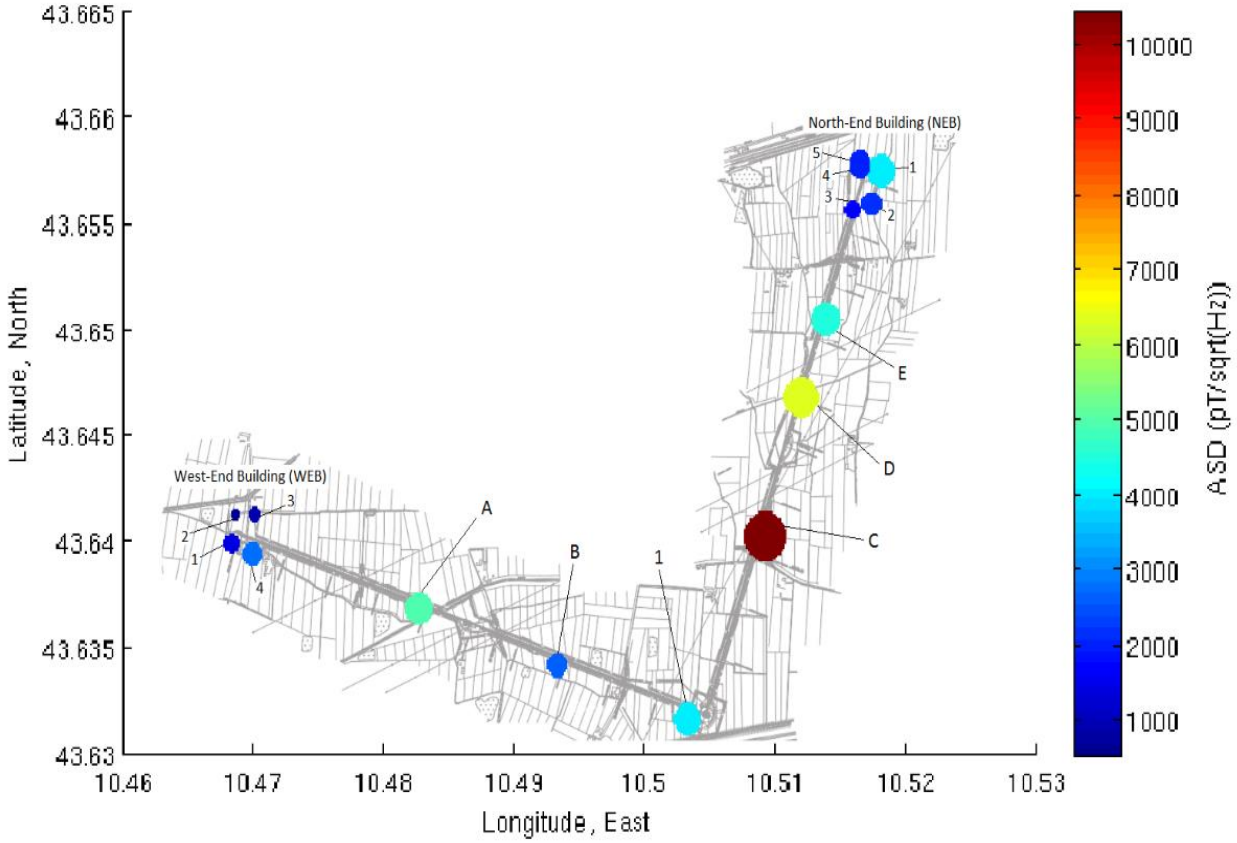
- Coherence with LHO magnetometers

[Thrane et al. 2013]

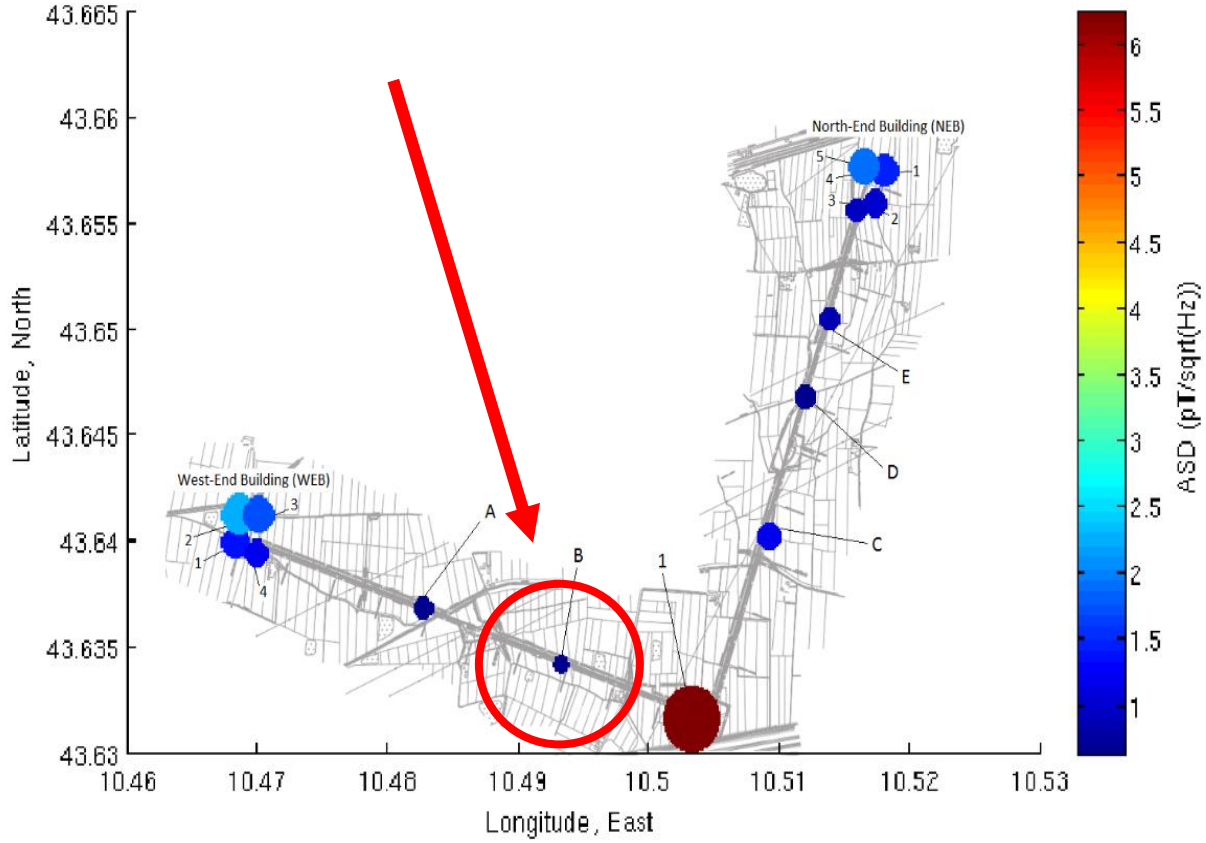
- Previous: $coh(7.8\ Hz) \approx 10^{-4}$ (3 months)
- Current: $coh(7.8\ Hz) \approx 10^{-2}$ (1 week)

On-site location testing

50 Hz ASD Component

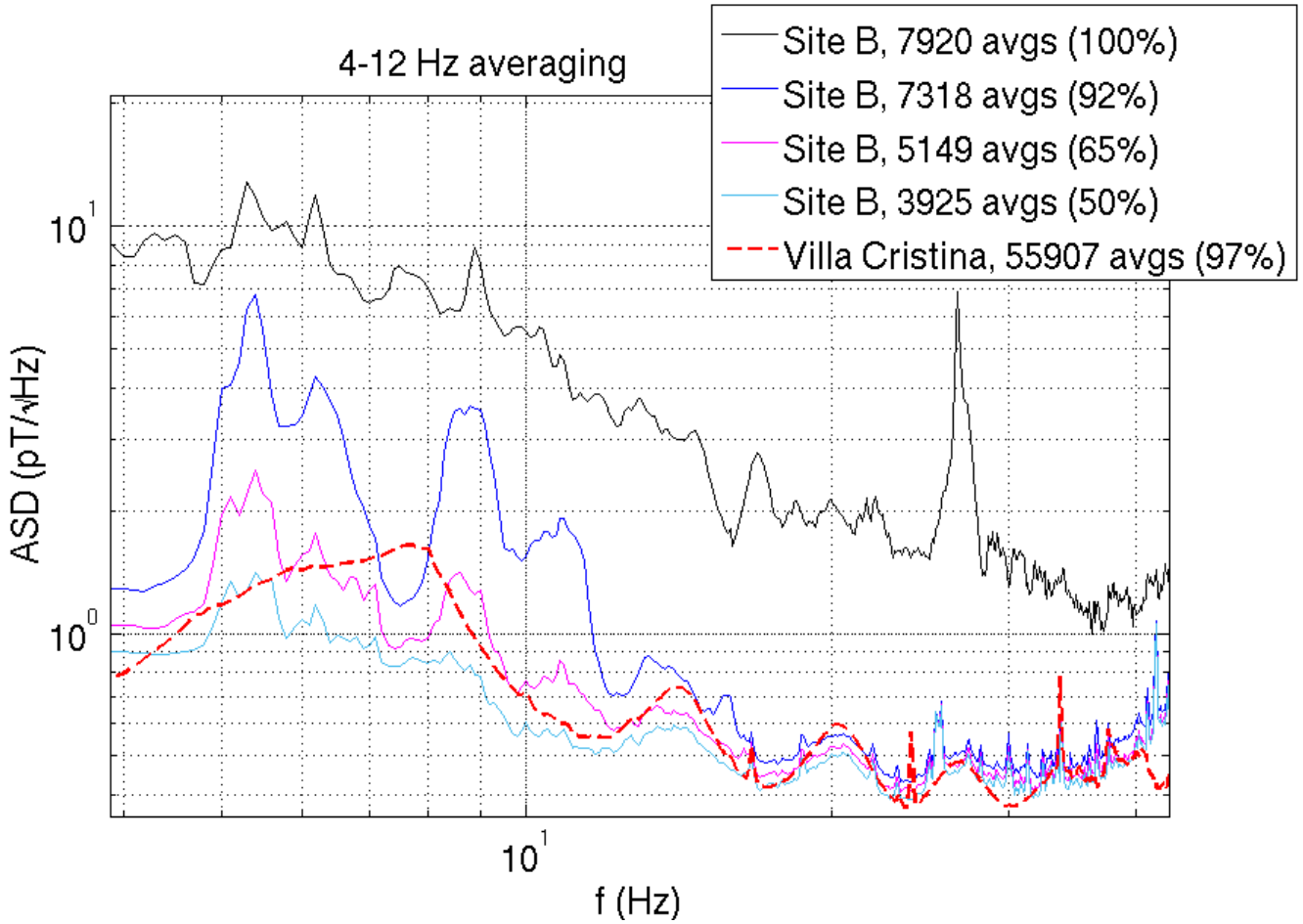


10-30 Hz Avg. ASD Component



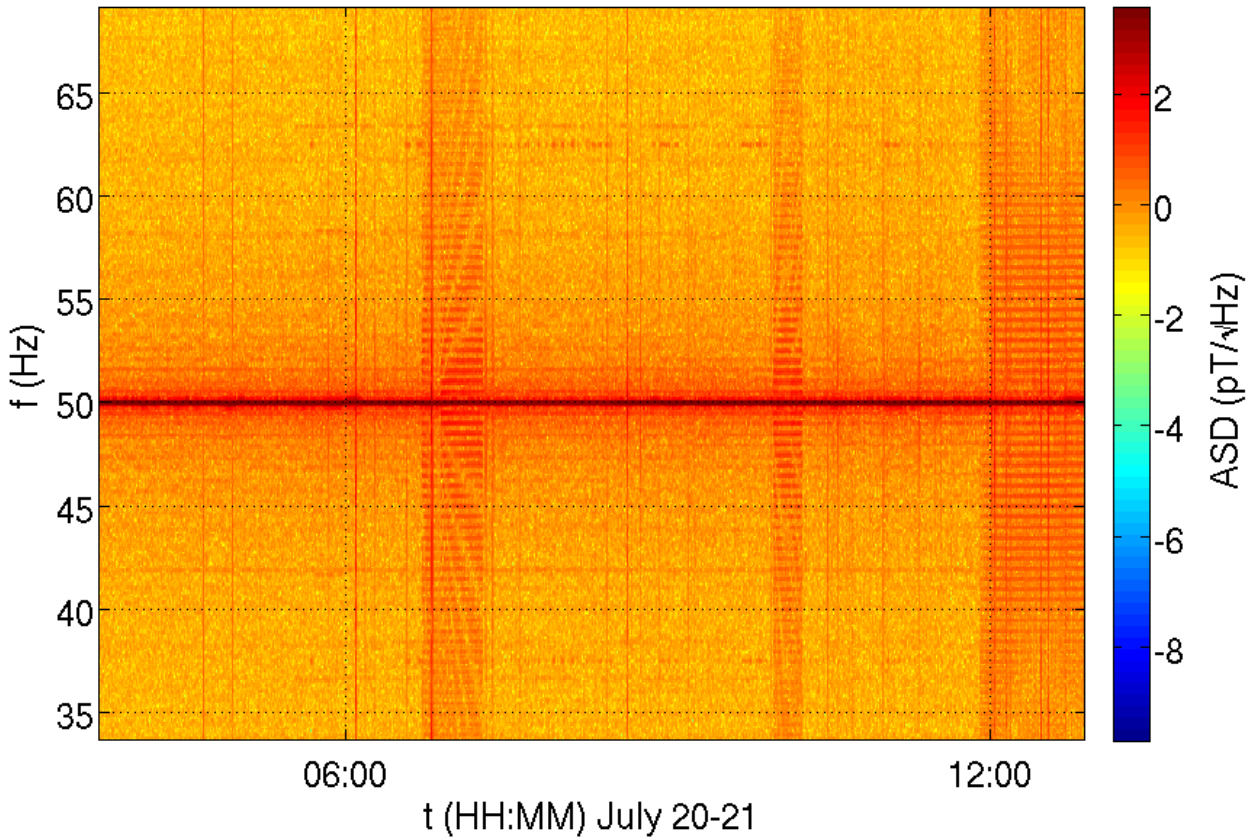
- Average ASD at each location (32-64 averages)
- ASD(f) for different frequencies compared

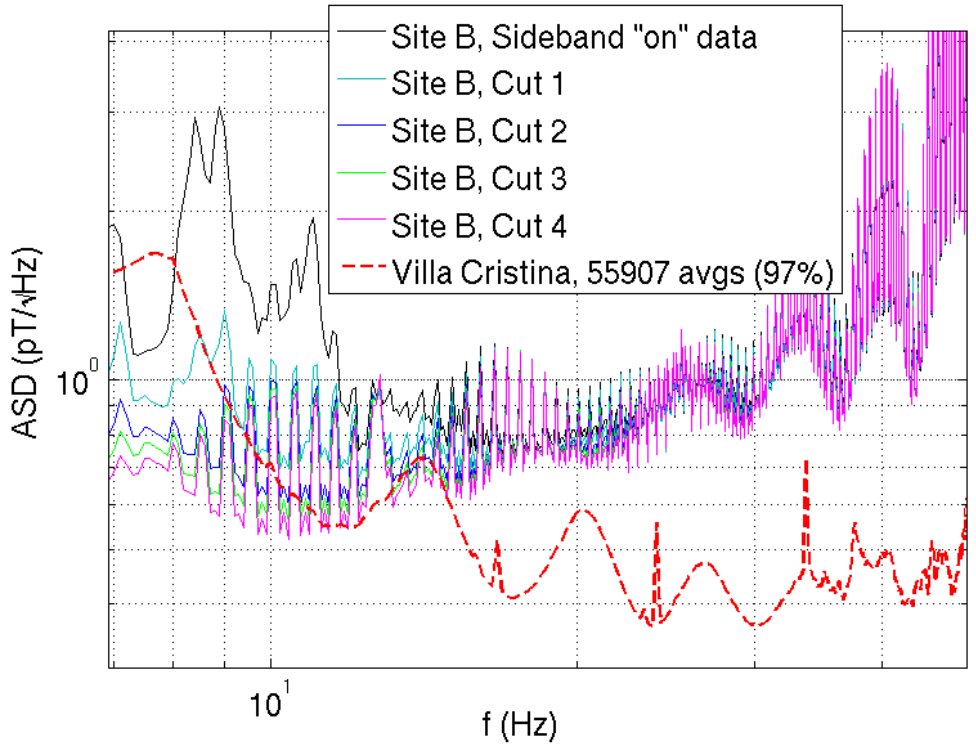
On-site installation: West Arm, 1 km



- 3/4 primary resonances resolvable after only 35% reduction

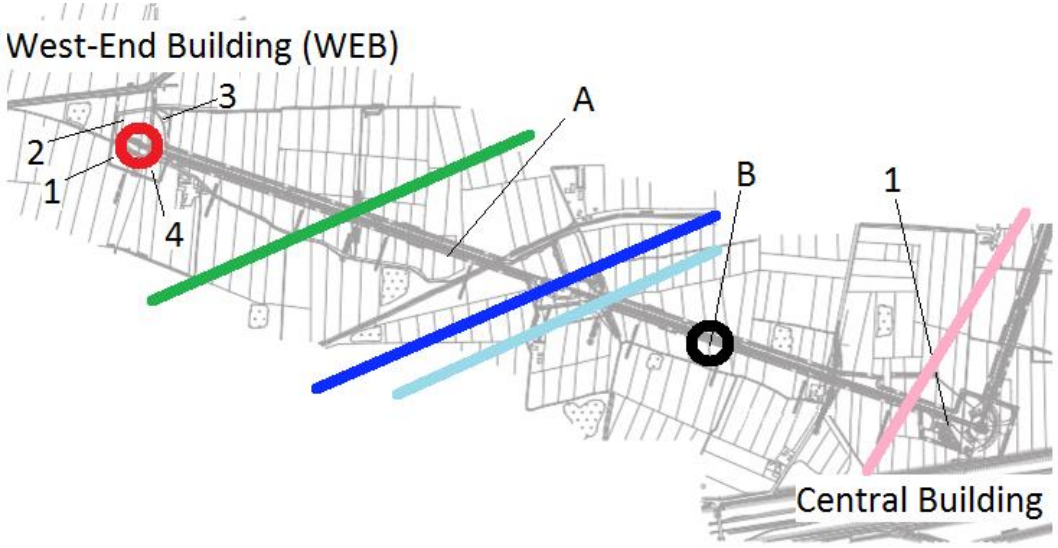
West Arm, 1 km: Sideband noise



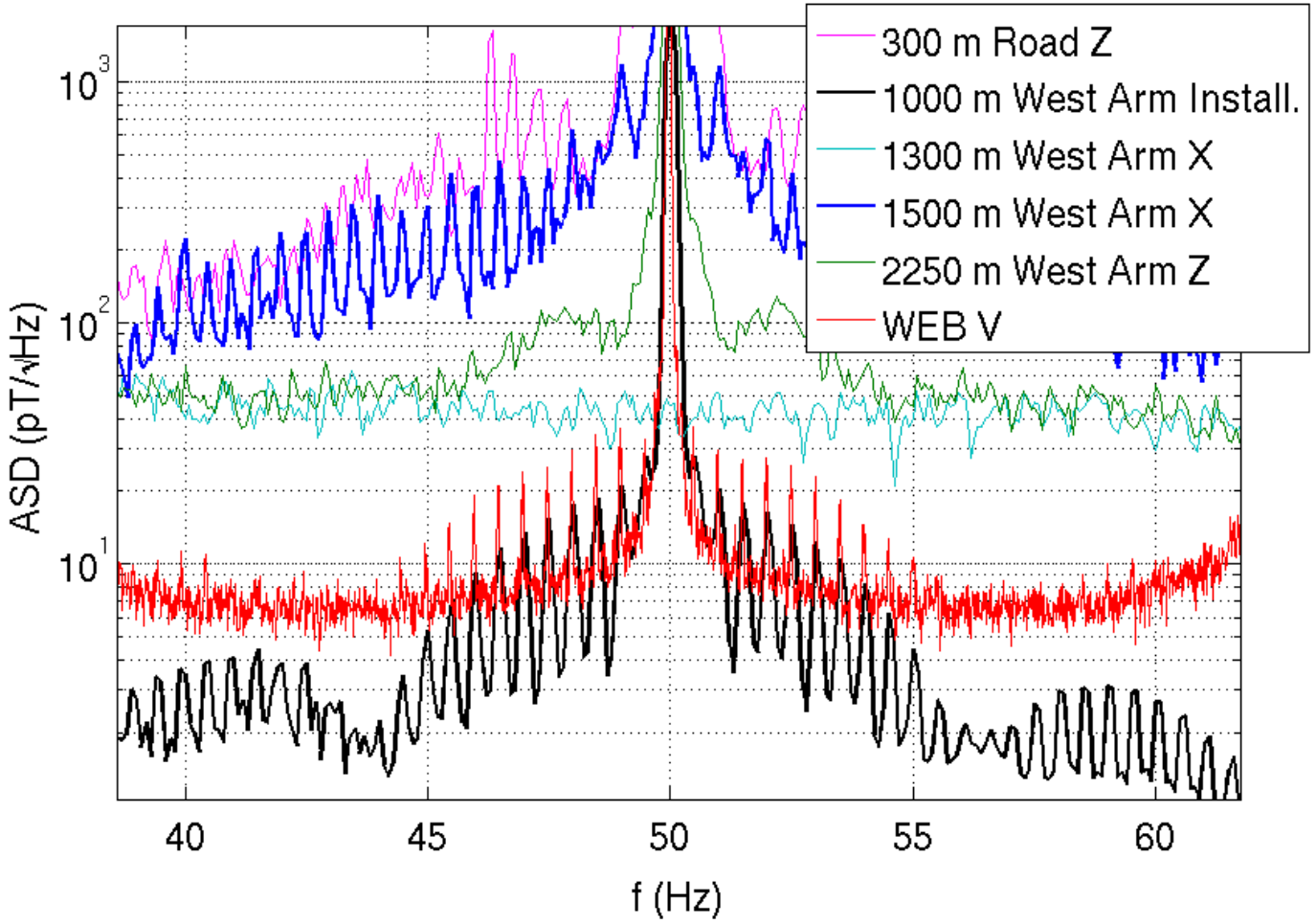


- Sideband noise turning on and off
- During sideband “on” time, resonances completely obscured

Sideband explanation

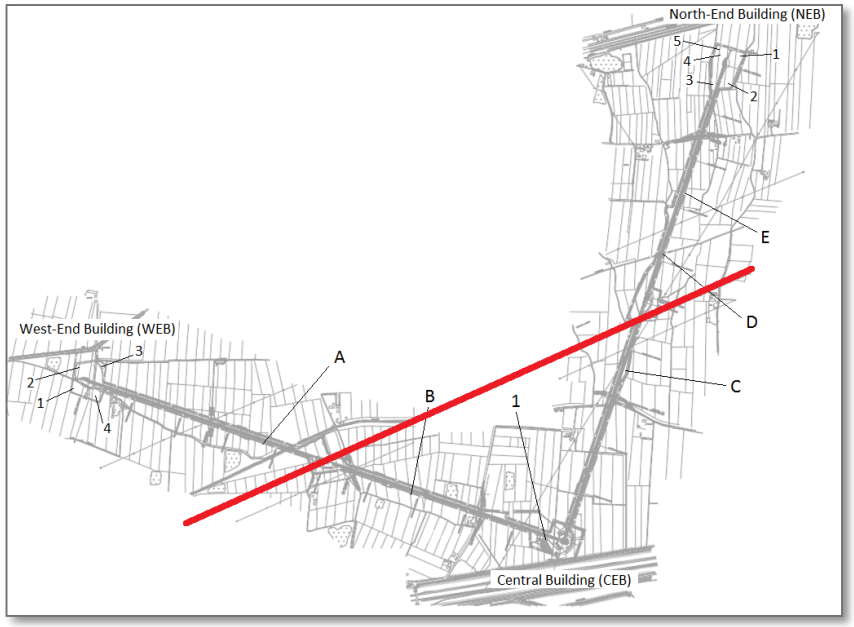


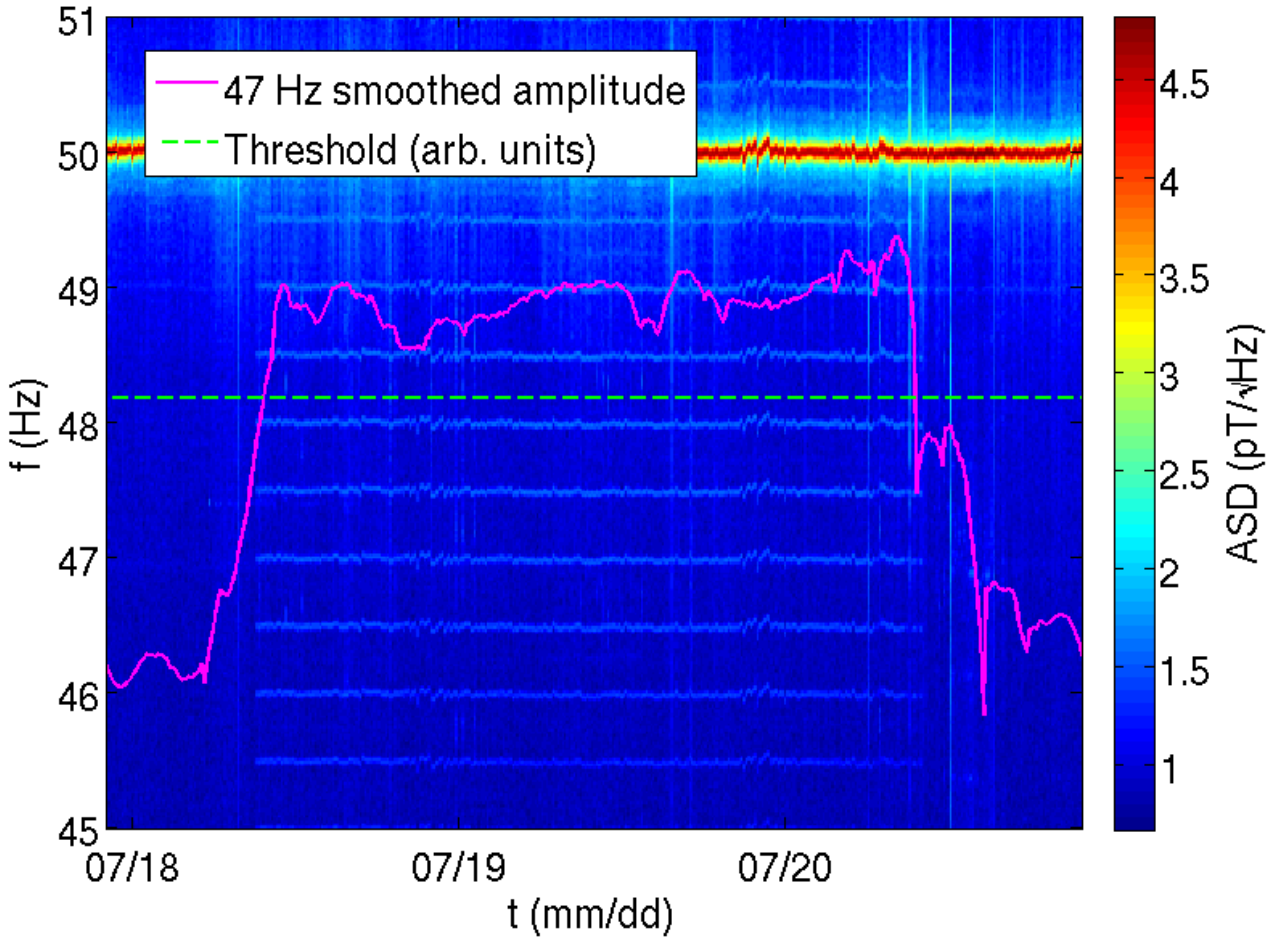
- 230 kV line sidebands (dark blue)
- WEB vertical sidebands (red)
- Investigate further down the road



Moving forward

- Should we stay or should we go? Efficiency of location
  - Algorithm for percentage of “on” time and past occurrences
    - WEB V: data since February 2015

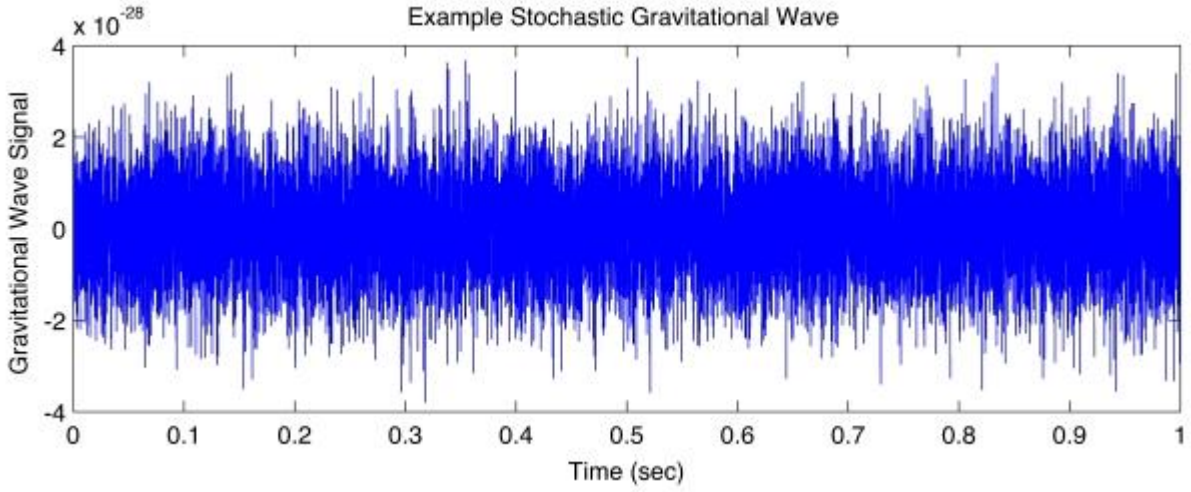


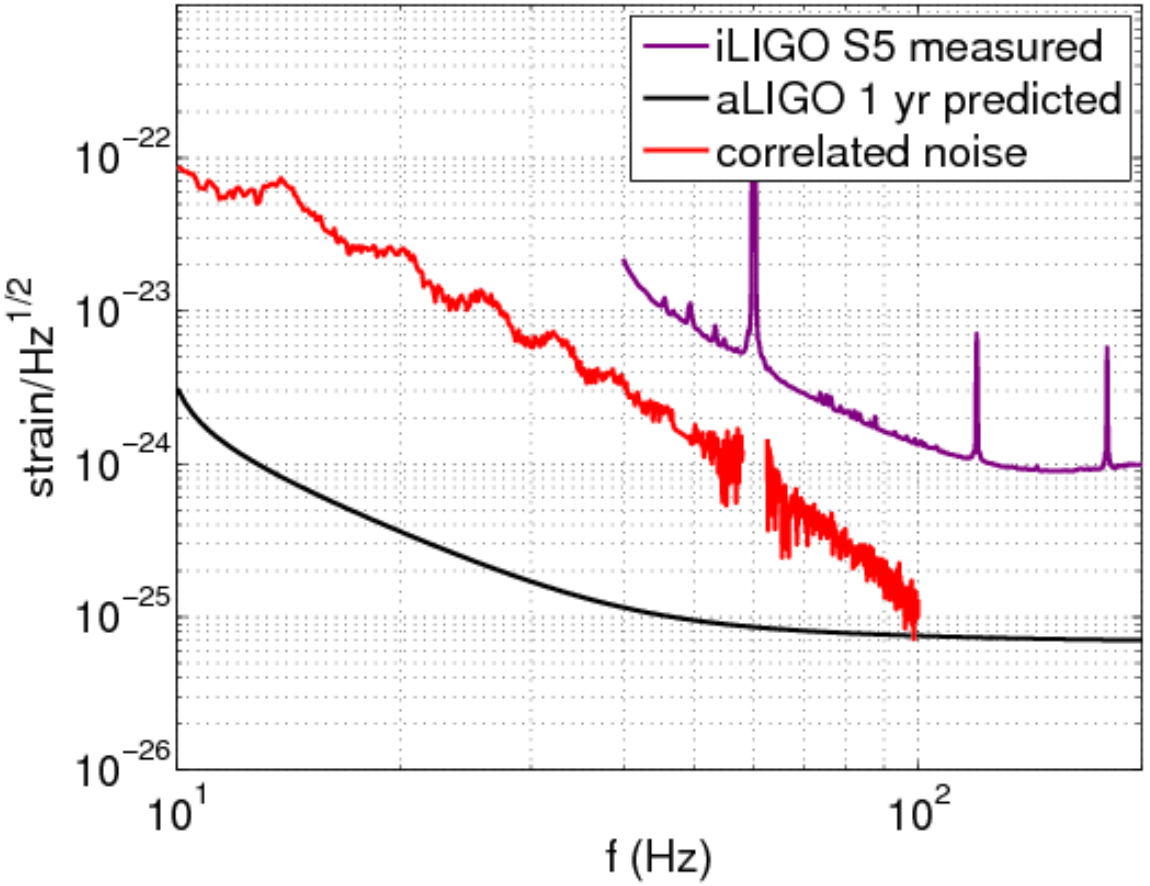


Stochastic GW Background (SGWB)

Arise from a large number of random, independent events

- Primordial or astrophysical origin
- Detection: Cross-correlating strain data
- Limited by correlated noise





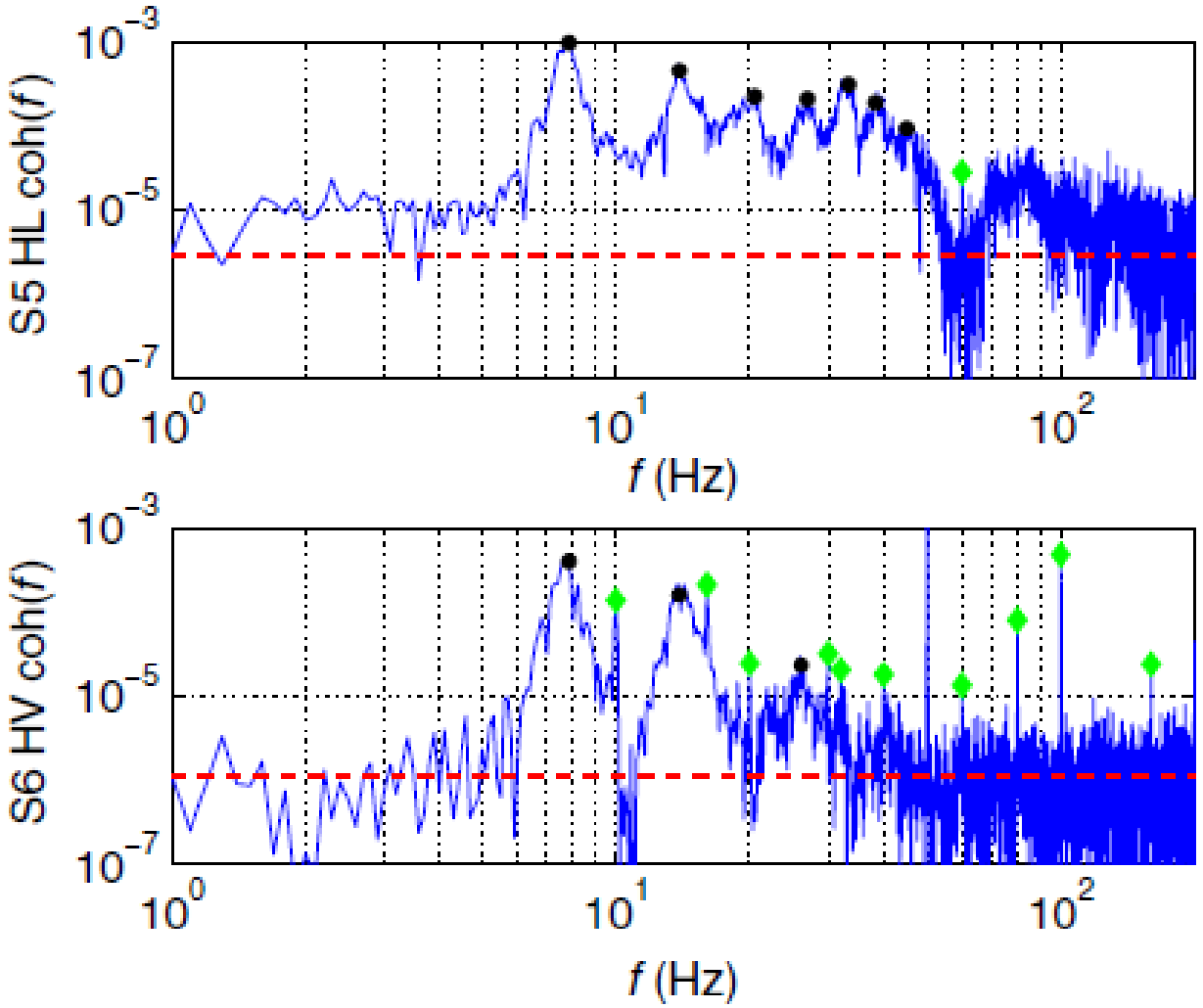
[Figure from Thrane et al. 2013]

Wiener filtering and coherence

$$r(f) = \frac{1}{\sqrt{1 - coh(f)}}$$

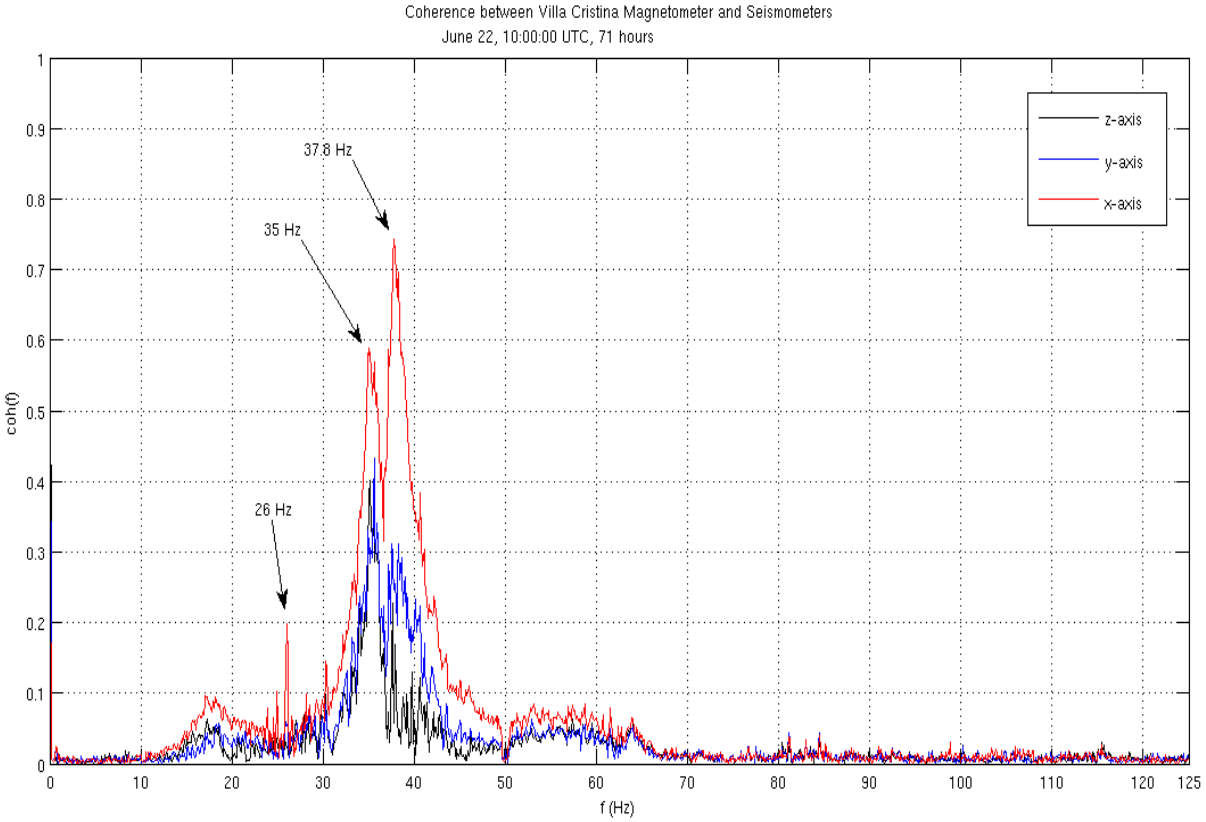
$$coh(f) = \frac{\overline{\tilde{s}_1^{\,*}(f)\tilde{s}_2(f)}^2}{\overline{|\tilde{s}_1(f)|^2}\;\overline{|\tilde{s}_1(f)|^2}}$$

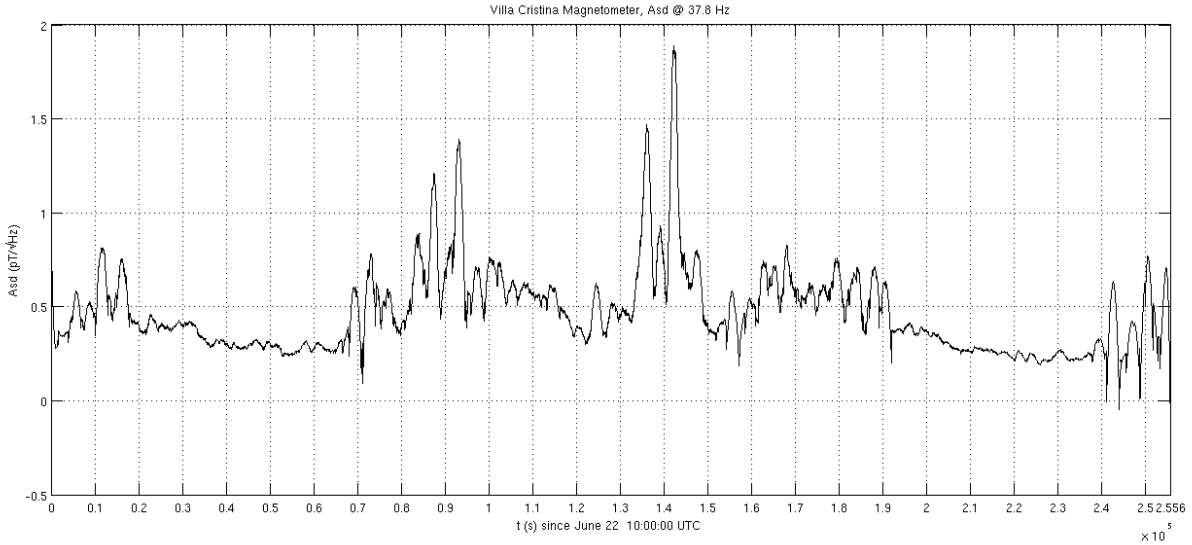
$\tilde{s}_1(f)$ – Fourier transform of the data series measured by detector *1*

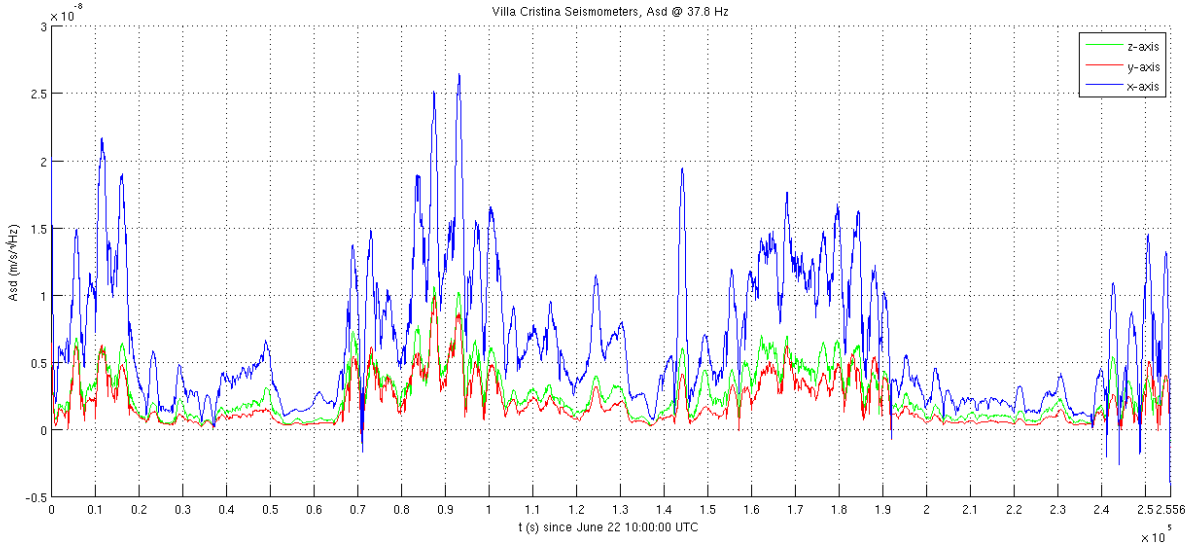


[Figure from Thrane et al. 2013]

Villa Cristina noise







- Magnetometer vs. seismometer coherence
  - Specific frequencies

Sideband WEB, NEB, IPS coherence