In situ surface radio calibration

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Gen2 Calibration Workshop

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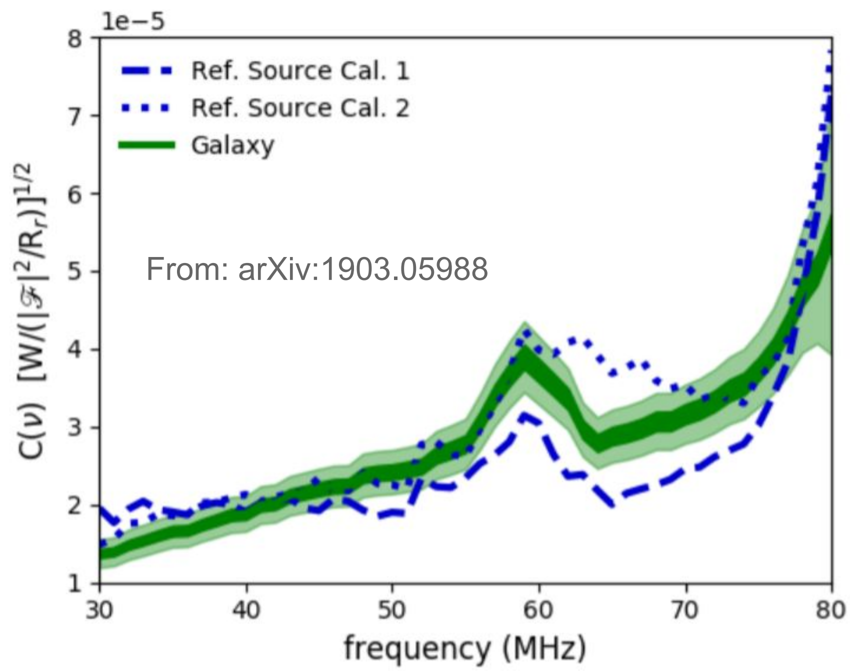
Motivation

- Lab calibration of electronics relies on assumptions on how to individual parts work together
- Can miss effects that are only present in the field

→ Use the Milky Way as a calibration source in the field

- Offers an additional cross-check
- Method has been successfully demonstrated by LOFAR



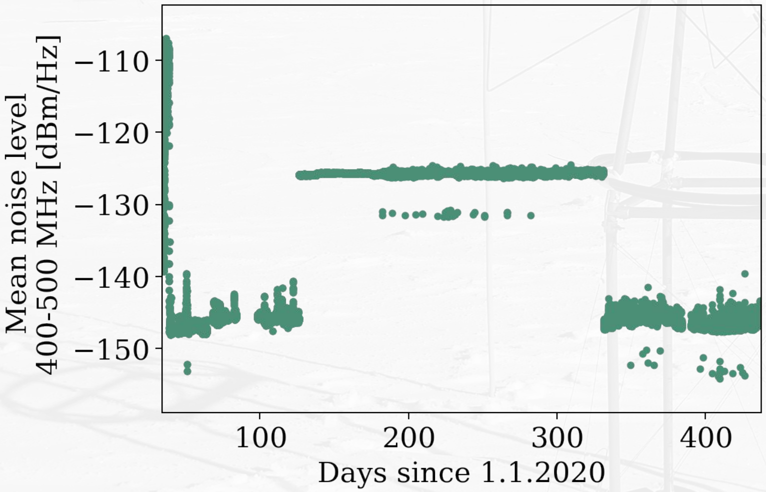
Radio data from the Pole

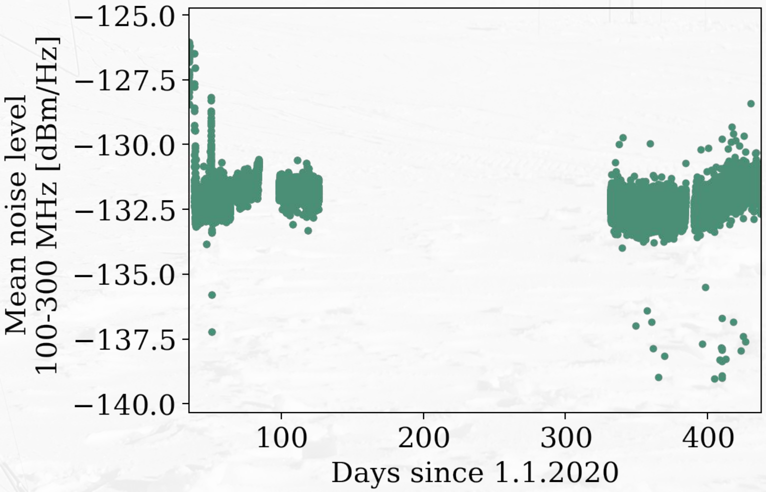
- **Jan 2020:** A full prototype station deployed
  - 3x Antennas
  - 8x Scintillator panels
  - 1x Field hub
- Physics data
  - Triggered by scintillators observing a shower
- Background data
  - Recorded every ~10s by a software trigger
  - Used for various calibration and detector performance studies
- For each trigger we record:

  3 antennas x 2 polarisation x 1/4μs traces
  - 1 GHz sampling frequency

Detector monitoring

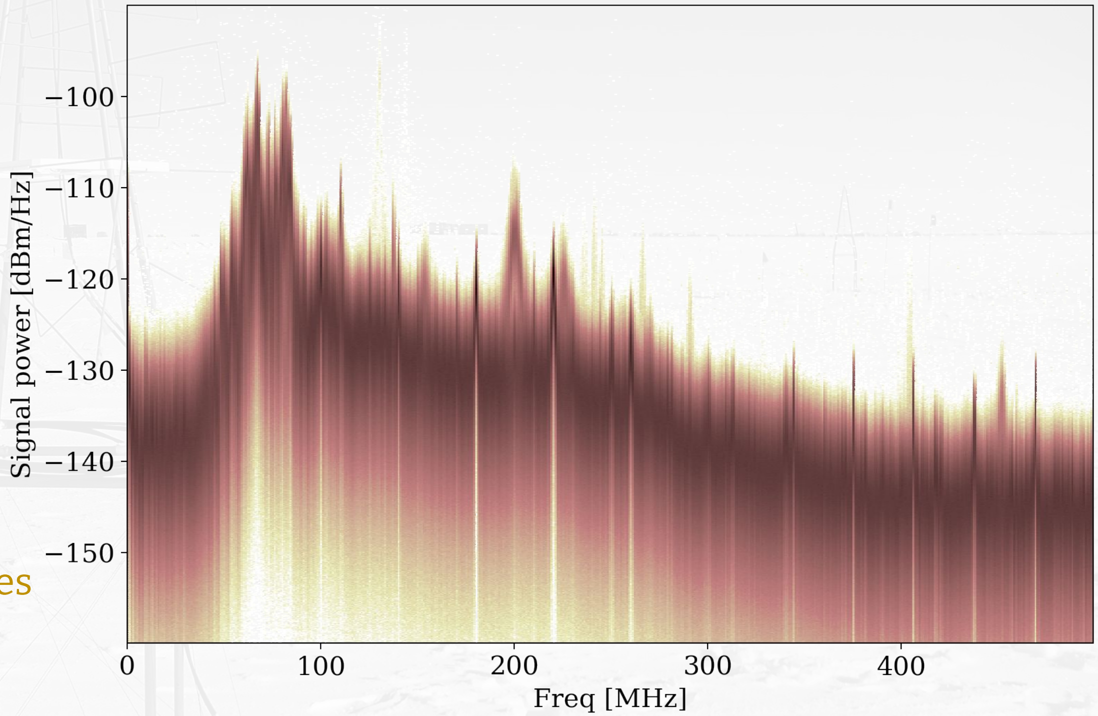
- Background data is used for monitoring of the detector performance
- Increased noise period due to software issues excluded from the analysis here
- An automated monitoring system could find such issues in the future





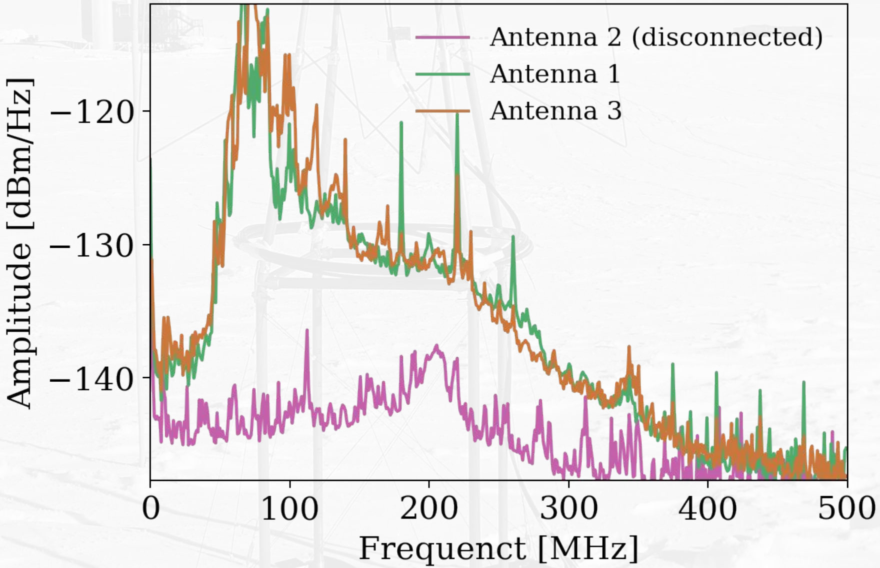
Radio noise sources

- Compute spectral power for each BG trace
  - Stack the spectra to obtain the power distribution
- Expected sources of the BG
  - Galactic radio emission
  - Noise of the amplifier and readout electronics
  - Man-made RFI
    - Some of this noise seems constant while other varies strongly with time



Electronic noise contribution

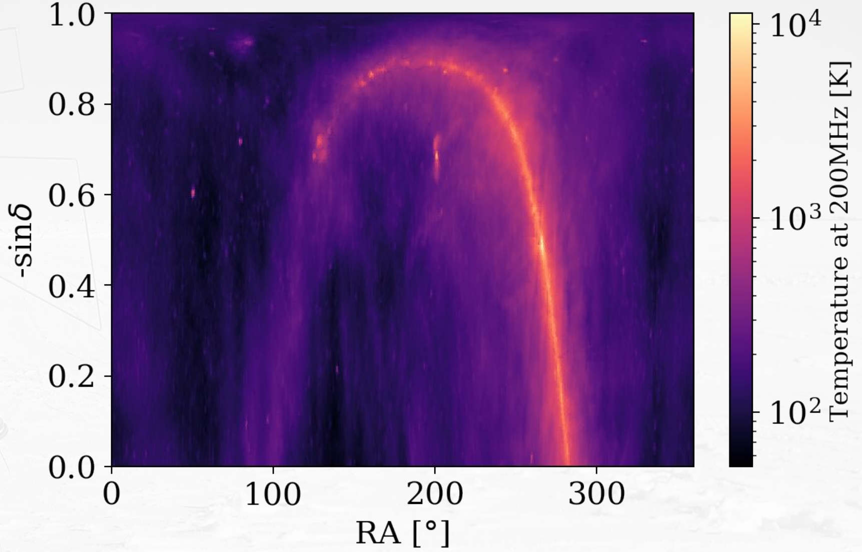
- ~1 day of data was recorded with one of the antennas disconnected
    - Only electronic noise is measured (& possibly RFI picked up though the cables)
    - Only significant at very low and high frequencies
        - Not very relevant for air-shower detection (~100-300MHz)



Galactic noise

- Use LFmap to get radio sky maps for each frequency
- Convolve the spectrum with the antenna response

→ Expected Galactic noise for a given antenna orientation

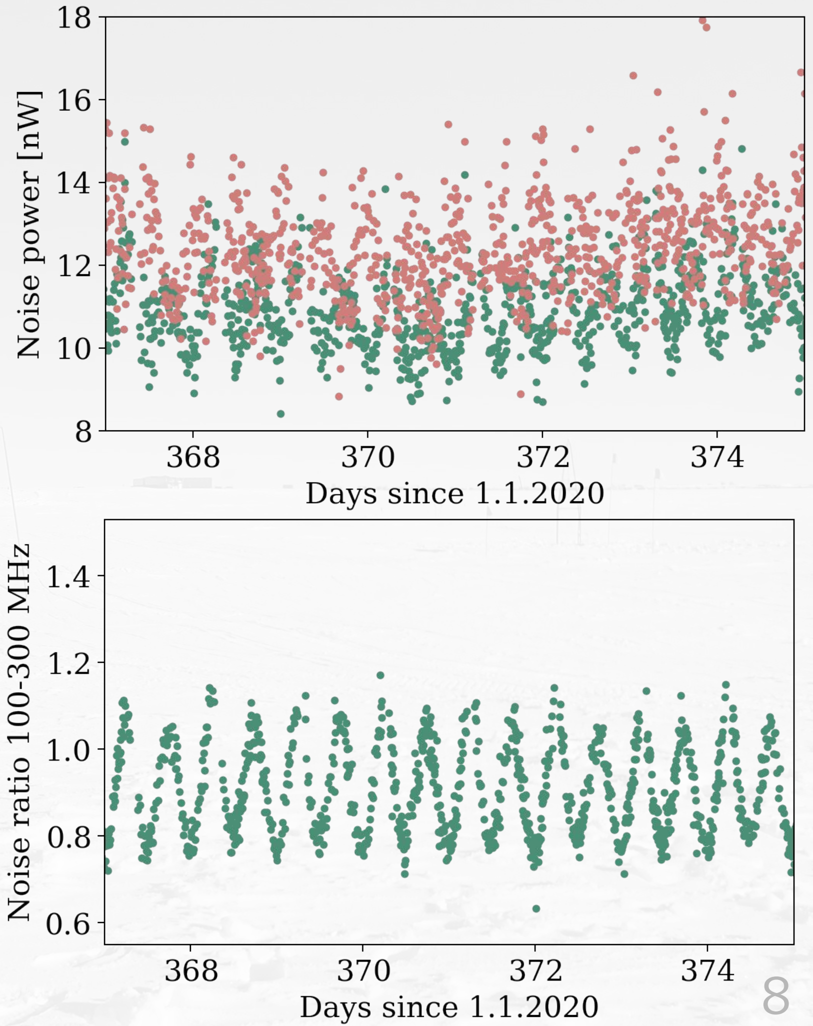


Galactic noise oscillations

- Galactic emission and antenna pattern highly anisotropic

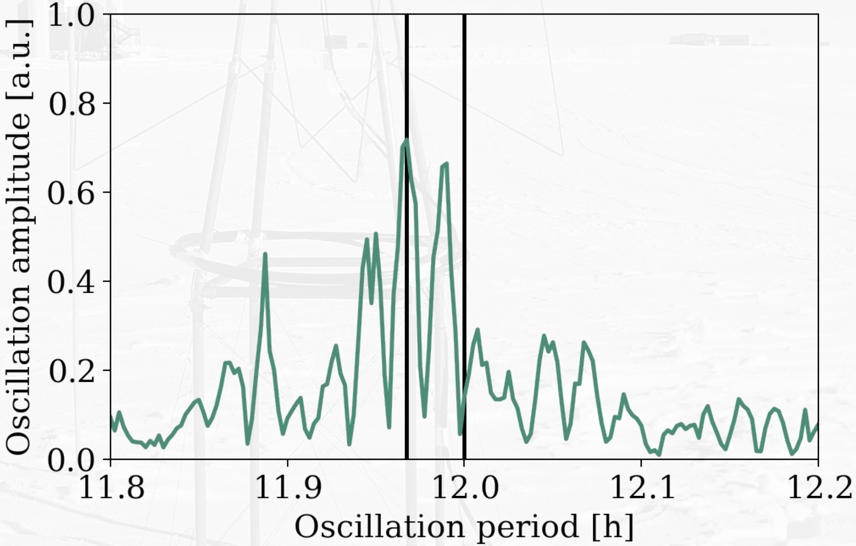
  → Noise amplitude expected to oscillate with period of ½ sidereal day (~11.97 h)

- To compensate for noise variations due to other effects, look at the noise ratio between two polarisations



Oscillation period

- Oscillation amplitude fitted for various periods
  - Best fit 11.97h matches with ½ sidereal day
  - 12 h period (solar or terrestrial noise sources) not dominant



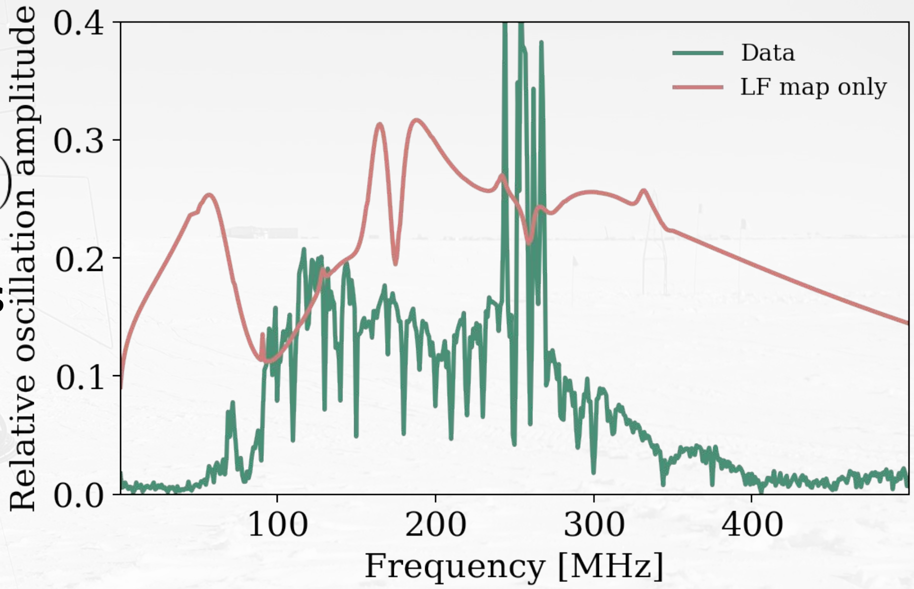
Oscillation amplitude fits

- An oscillation fit is performed for each frequency:

$$P_{tot}(f) = P_0(f) \cdot (1 + A(f) \cdot sin(\omega t + \phi(f)))$$

Period and phase fixed to expected values

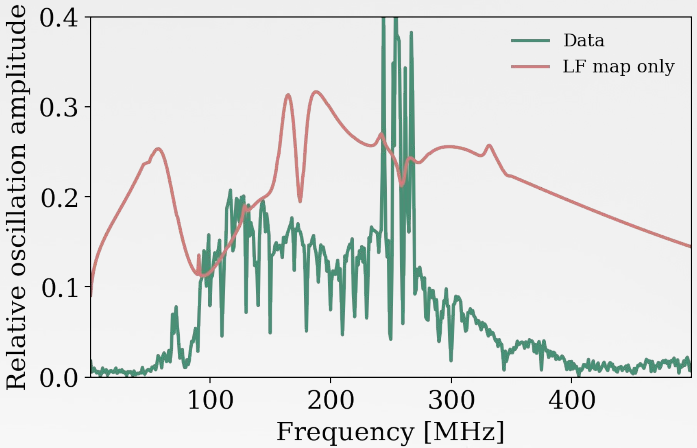
Relative oscillation amplitude A(f) fitted

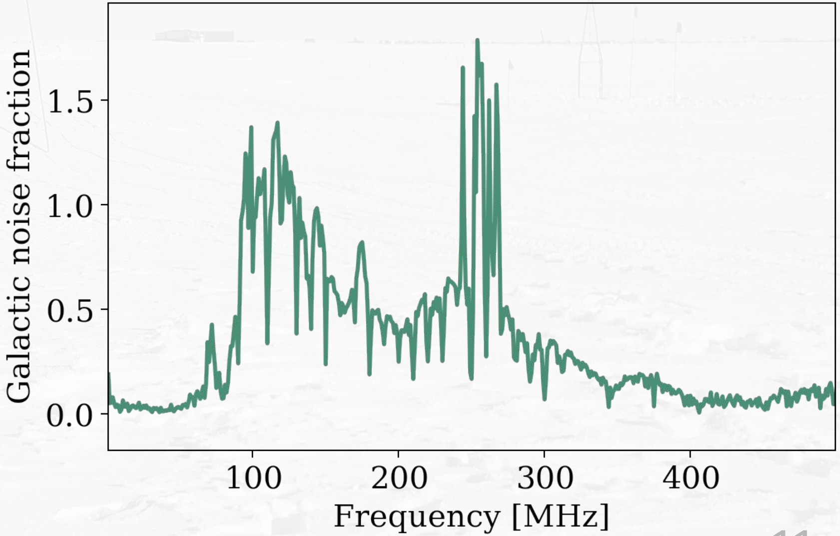


Galactic noise fraction

- Assume only the galaxy contributes to the oscillation at the ½ sidereal day period
- Can get relative content of the galactic noise at each frequency
  - Fraction >1 indicates RFI contamination in the oscillations

$$\frac{A_{\text{observed}}(f)}{A_{\text{predicted}}(f)} = \frac{A(f)}{BG_{total}} \cdot \frac{BG_{gal}}{A(f)} = \frac{BG_{gal}}{BG_{total}}$$

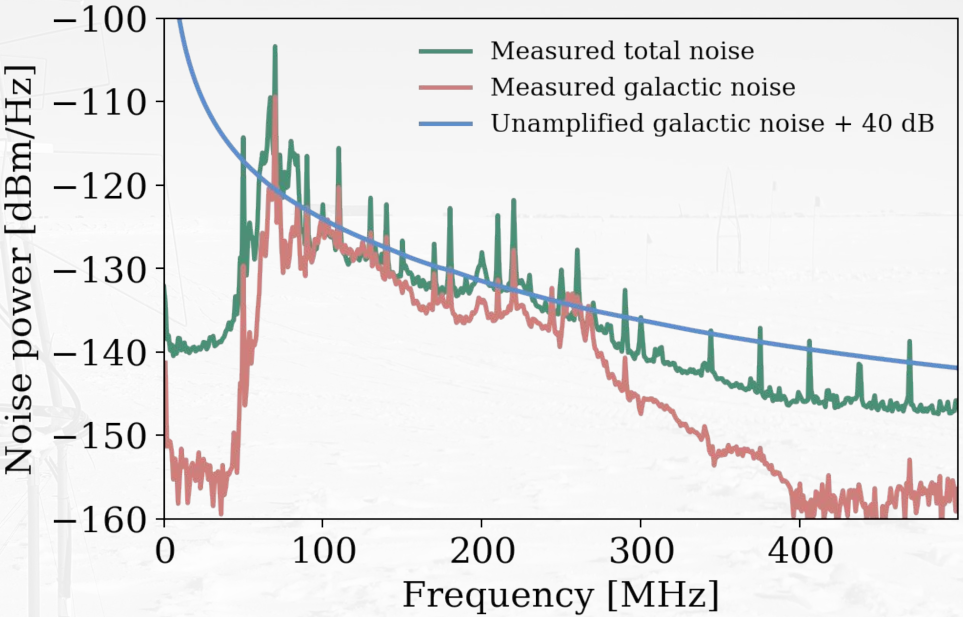




Galactic noise spectrum

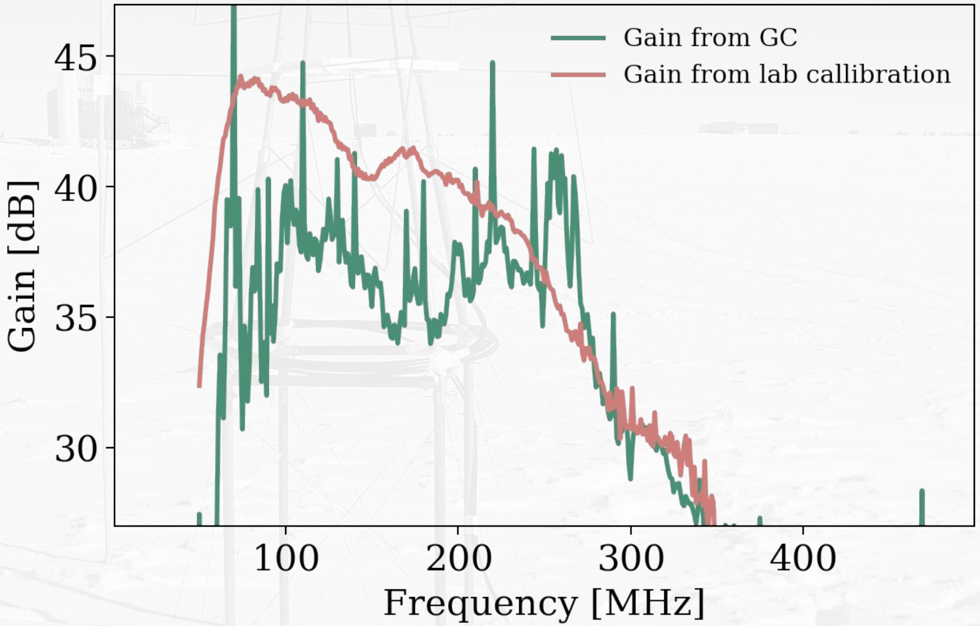
Total average noise corrected by galactic noise fraction

Unamplified spectrum prediction from LFmap



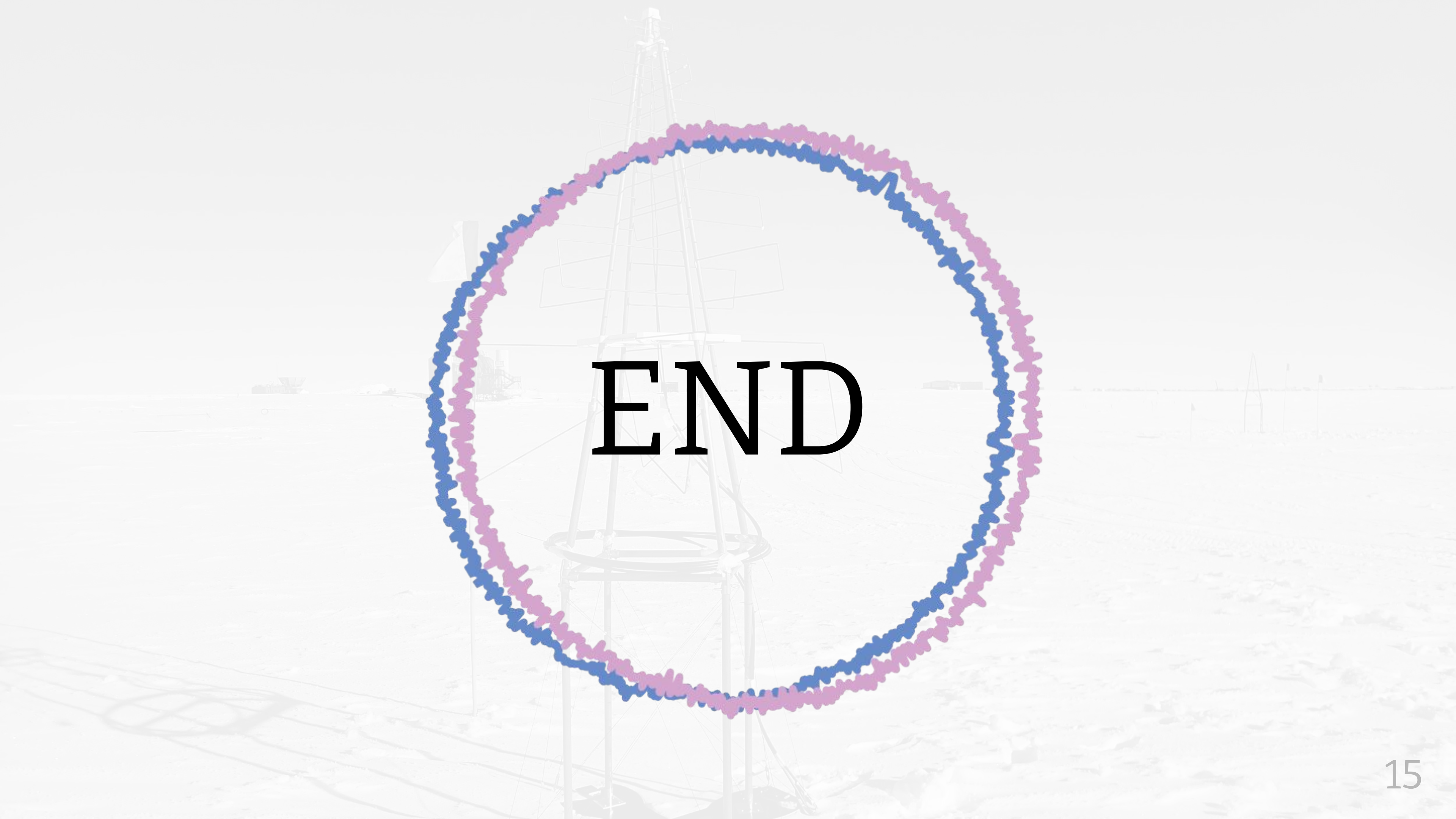
Galactic gain calibration

Electronic gain can be obtained from measured/predicted galactic spectra



Conclusions

- Human activity and Milky Way dominant noise sources at observed frequencies
- Galactic noise follow a predictable pattern that can also be seen in the data
- Electronics gain can be computed by comparing measured and predicted galactic spectra
    - Can offer a cross check for lab calibrations and monitoring of long-term detector behaviour
    - Currently a proof of concept, accuracy limited by RFI at the moment
        - <1 year of data mostly in summer
          → a lot of cross-contamination due to man-made transient noise
            - A longer data set would let the RFI get averaged out better
        - Current prototype station close to ICL → fairly high RFI
        - Long -term study of the RFI patterns needed to better disentangle it from the galactic background



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