

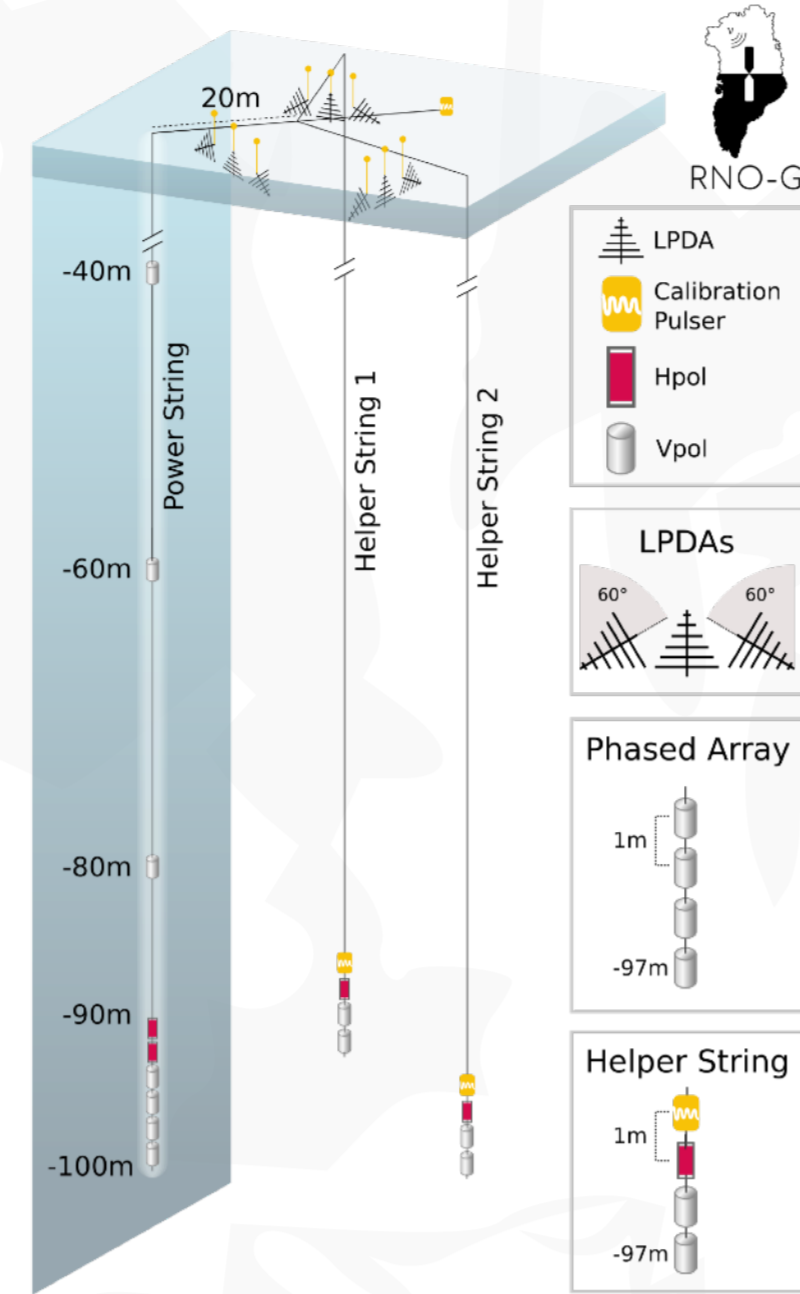
Solar radio flare observations with the Radio Neutrino Observatory Greenland (RNO-G)

Steffen Hallmann for the RNO-G Collaboration

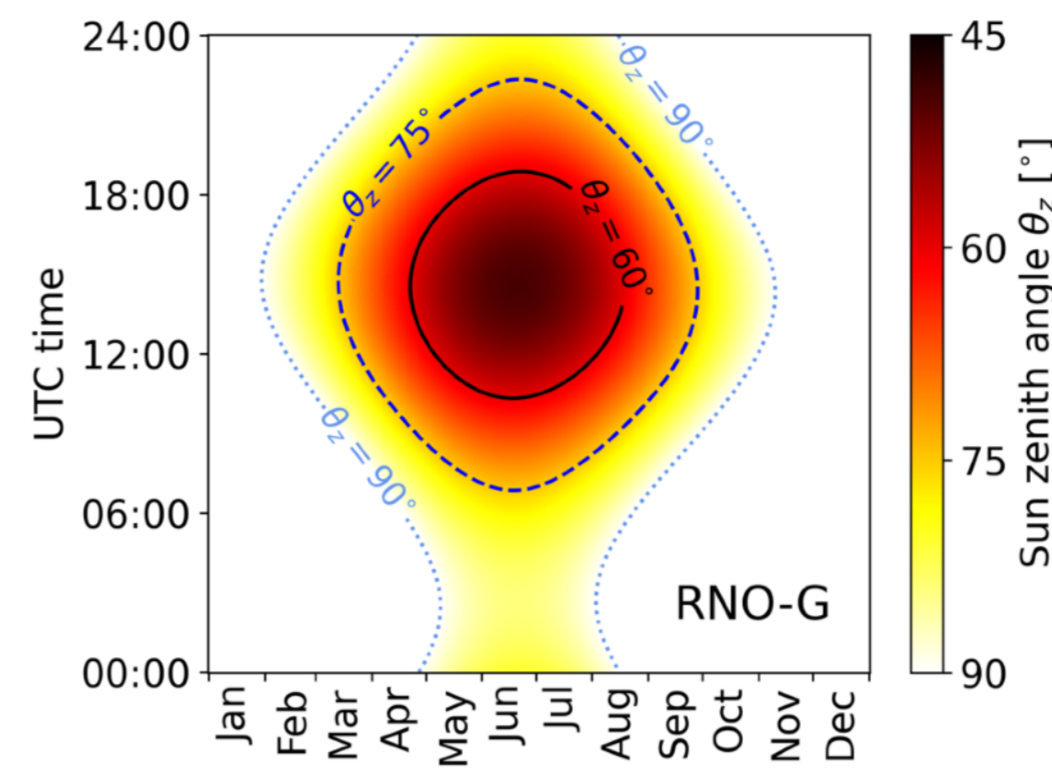
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RNO-G detector. [1]

- ☀️ designed to detect ultra-high-energy ($>30\text{PeV}$) neutrinos in ice via Askaryan radio emission [2]
- ☀️ located on top of 3 km thick ice shield at Summit Station, Greenland
- ☀️ 8 of 35 stations (24 antennas each) completed and operational
- ☀️ autonomous design:
 - solar+wind powered (25 Watts consumption)
 - wireless communication and data transfer

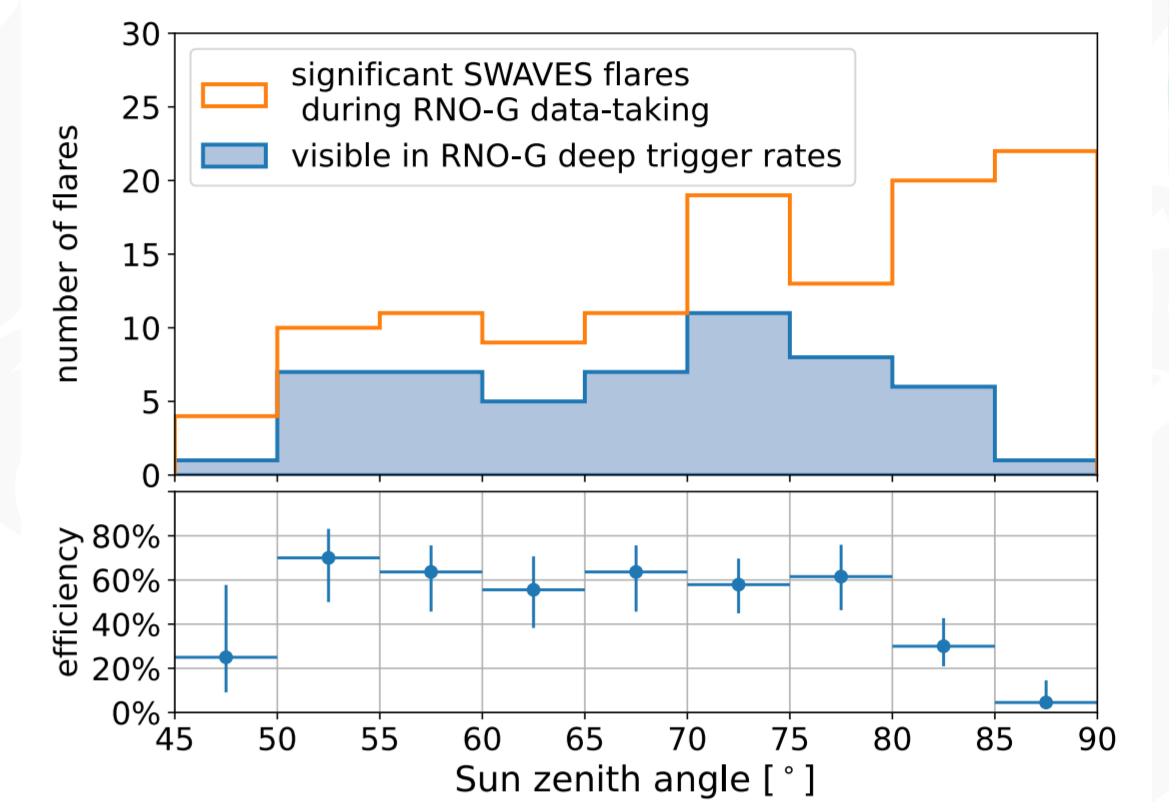


Identifying solar radio flares.



- ☀️ Continuous operation when Sun is above horizon for RNO-G
- ☀️ detector at 73° latitude: 100% visibility during summer months

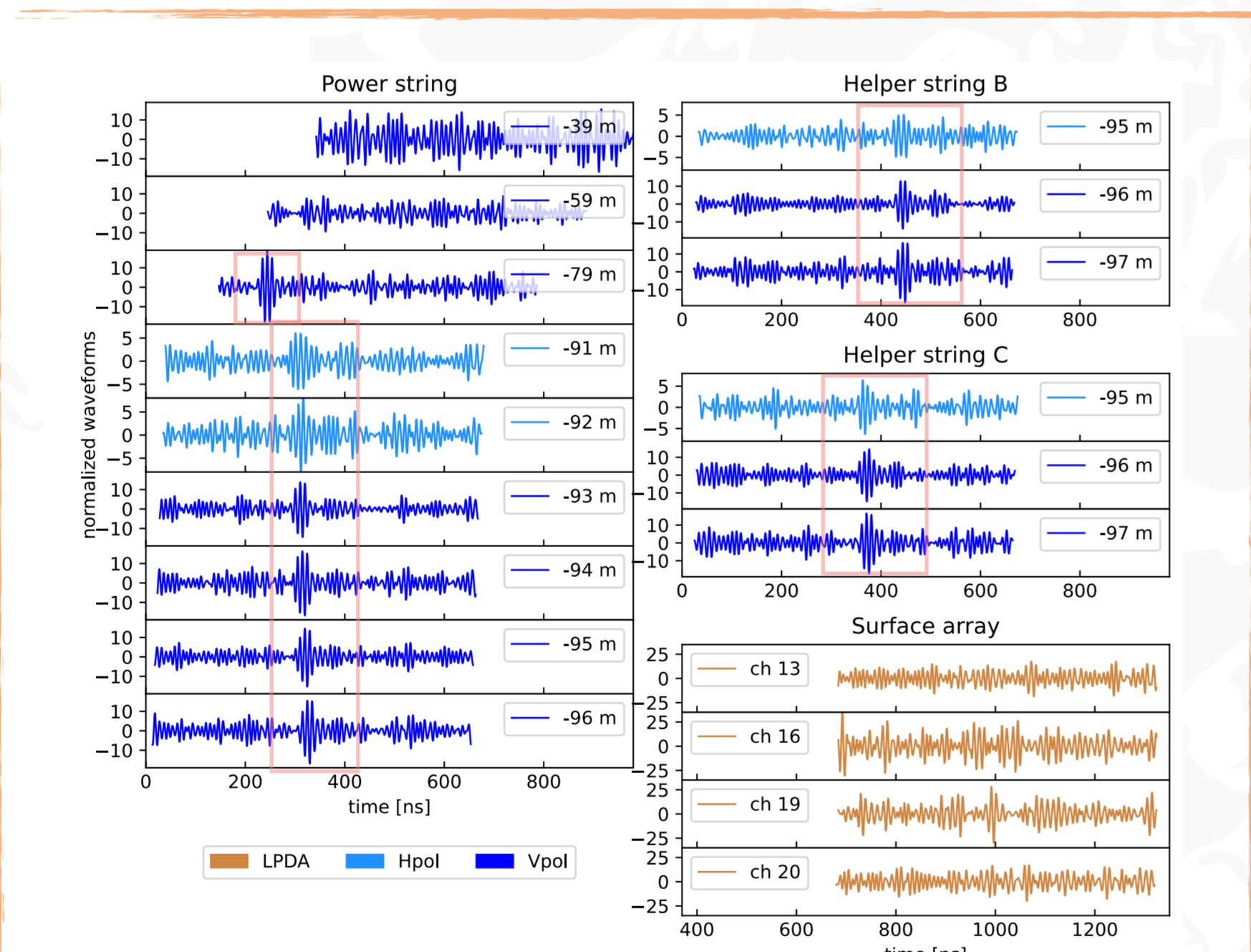
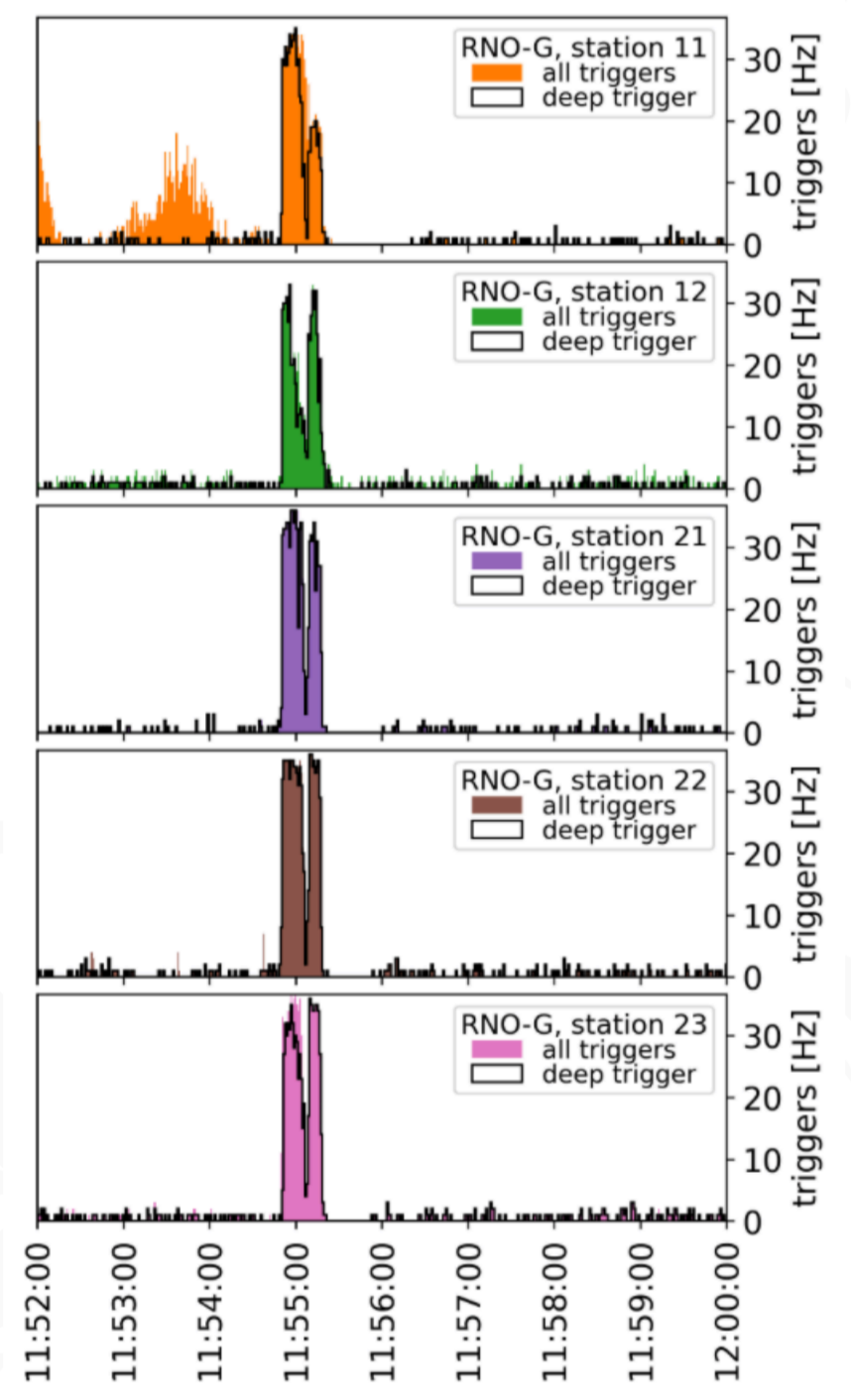
- ☀️ solar flares visible down to 10 degrees above the horizon (shown using SWAVES satellite excesses [4])
- ☀️ currently few flares per week evident in trigger rates by eye
- ☀️ in 2022/23 data: observed 75 flares in coincidence with the Callisto network [3], most of them type III



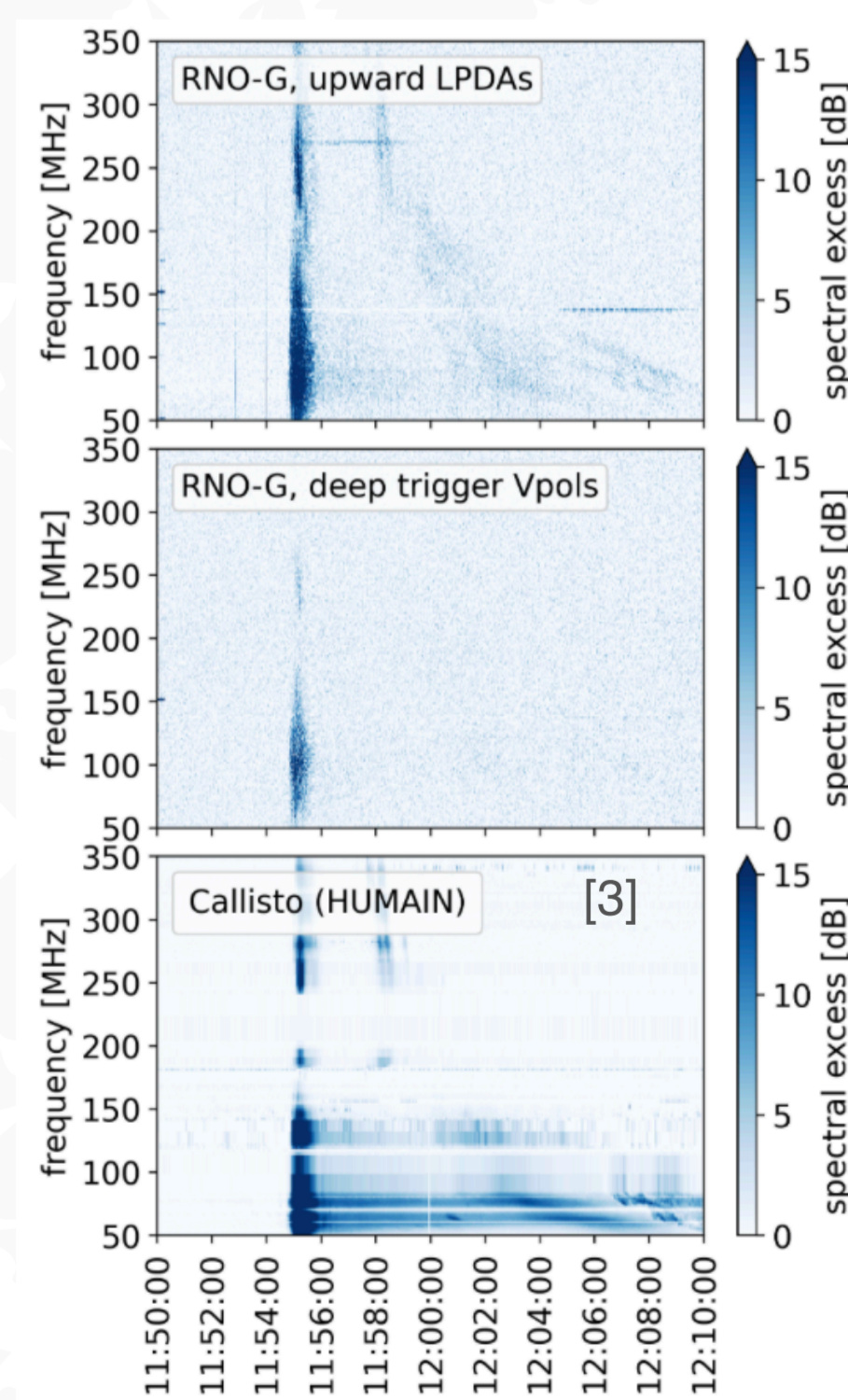
An instrument designed for time domain data.

Solar flare on Sep. 29, 2022

- ☀️ impulsive — mostly type III — solar radio flares able to trigger RNO-G stations
- ☀️ up to ~ 30 Hz trigger rate per station, with threshold close to the thermal noise floor

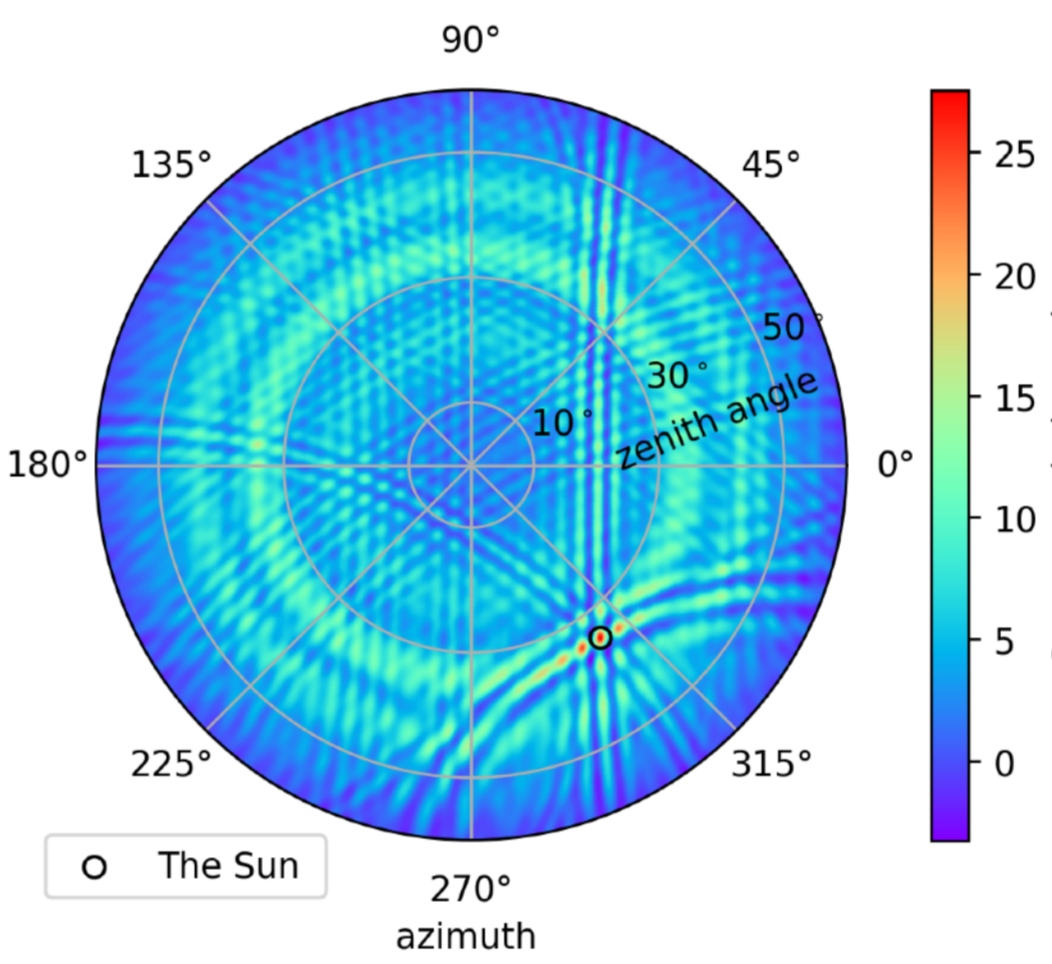


- ☀️ isolated nanosecond-timescale pulses in recorded data
- ☀️ **2.4 GSa/s, $1\mu\text{s}$ readout window**
- ☀️ combination of VPol + HPol antennas allow to constrain **signal polarization**



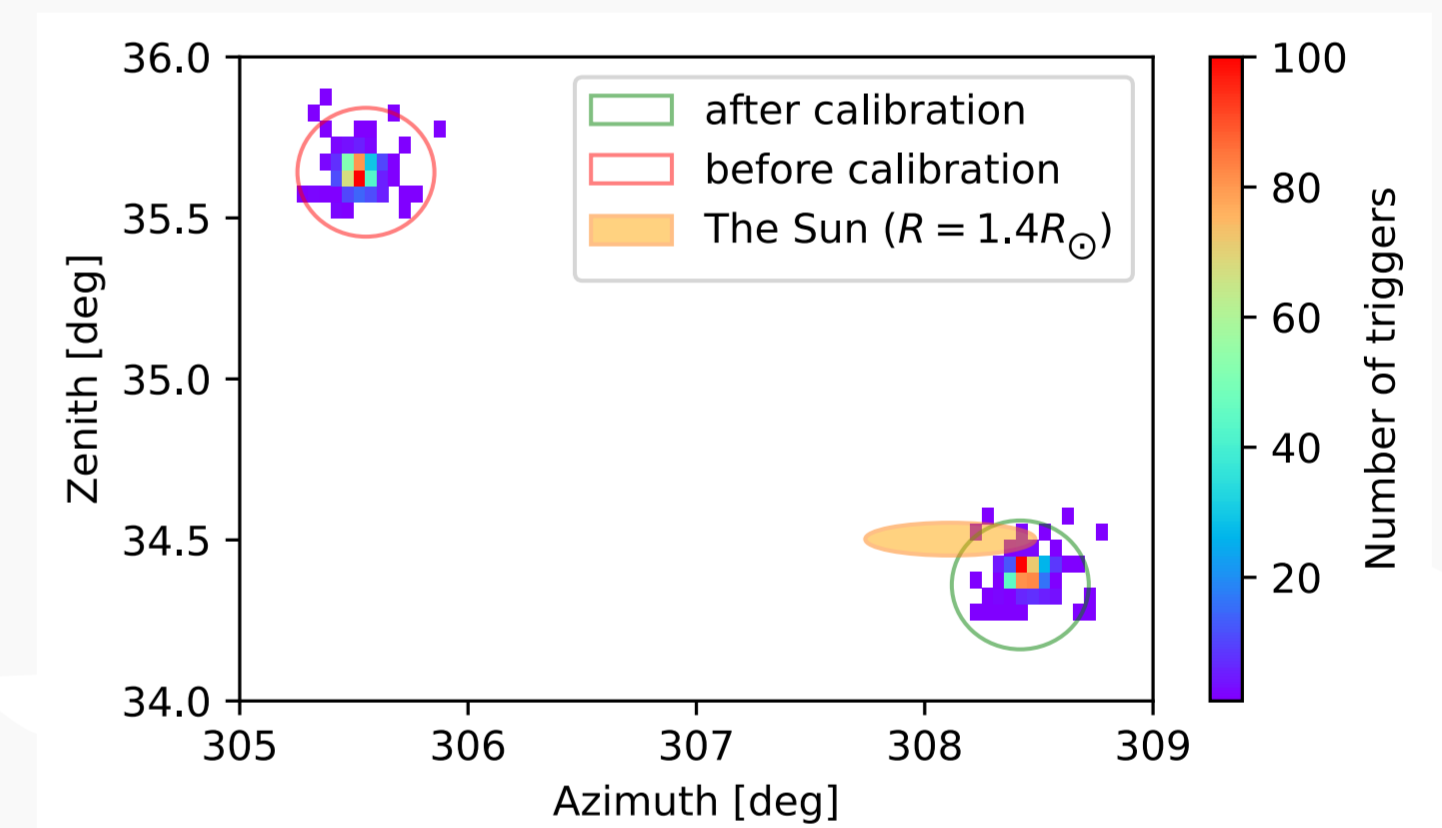
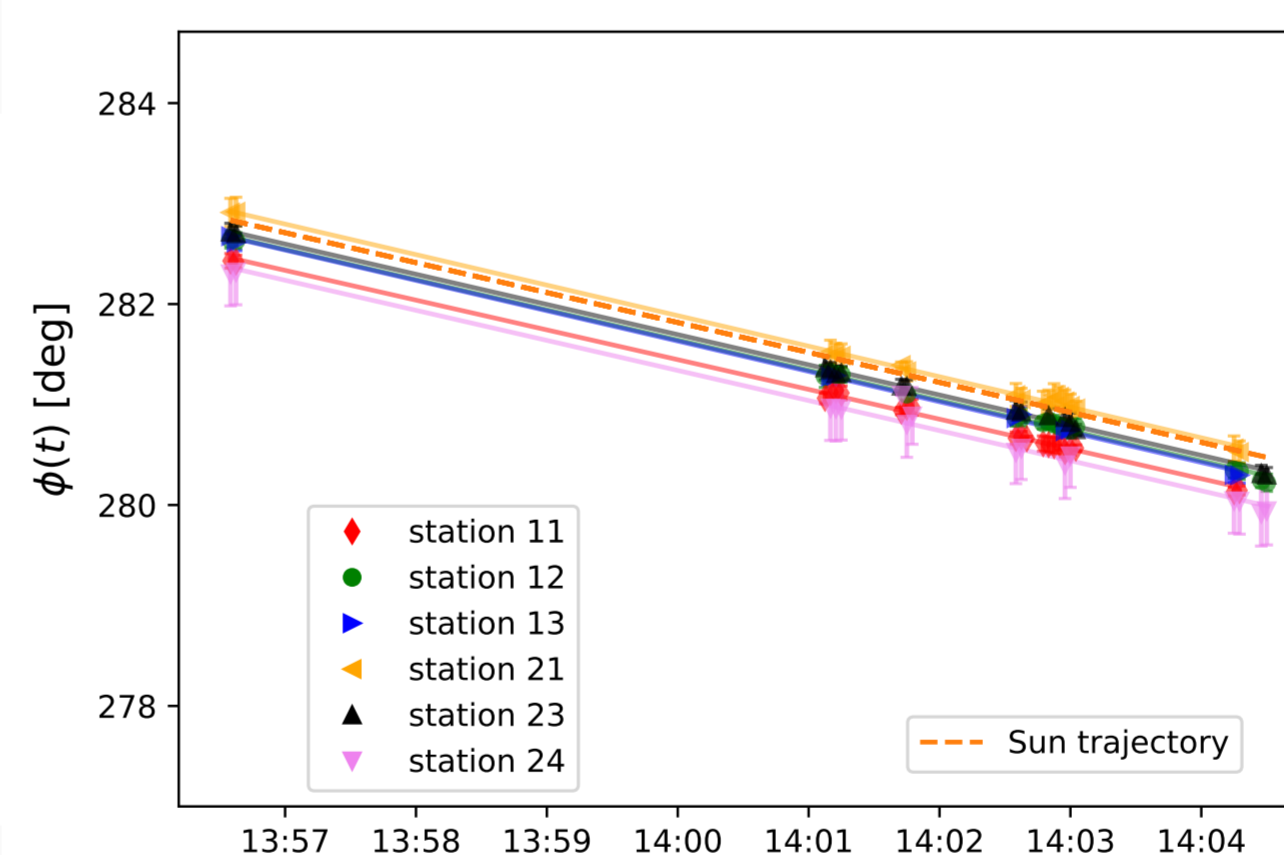
- ☀️ spectrograms show excess and frequency drift also in recorded background data not triggered by flare
- ☀️ instrument sensitive in $\sim 80\text{--}700$ MHz band

Flare direction reconstruction and detector calibration.



- ☀️ cross-correlating signals in from different antennas allows for direction reconstruction

- ☀️ Sun is a moving, far-away calibration source
- ☀️ 0.25° pointing accuracy on signal arrival direction demonstrated



- ☀️ subsequent type III flares allow for tracking the Sun on the sky

Unique opportunity for the solar physics community?

Frequency spectra and time domain traces available on disk since 2021. We are happy to share our data and collaborate.

- $O(10\text{ ns})$ short timescale pulsed emission and absolute time resolution
- polarization sensitivity provided by combination of HPol, VPol and LPDA antennas

References.

- S. Agarwal et al., "Solar flare observations with the Radio Neutrino Observatory Greenland (RNO-G)", *Astroparticle Physics* **164** (2024) 103024, DOI 10.1016/j.astropartphys.2024.103024
- [1] J.A. Aguilar et al., "Design and Sensitivity of the Radio Neutrino Observatory in Greenland (RNO-G)", *JINST* **16** (2021) P03025
- [2] for a recent review, see: S. Barwick, C. Glaser, "Radio Detection of High Energy Neutrinos in Ice", *World Scientific Series in Astrophysics, The Encyclopedia of Cosmology*, pp 237-302 (2023)
- [3] A.O. Benz, C. Monstein, et al., "A world-wide net of solar radio spectrometers: e-CALLISTO", *Earth Moon Planets* **104** (2009) 277-285
- [4] J.L. Bougeret et al., "SWAVES: The radio and plasma wave investigation on the STEREO mission", *Space Sci Rev.* **136** (2008) 487-528



Publication



Flare gallery



Contact us!

