6th Global 21cm Workshop

Institute for the Fundamental Physics of the Universe, Trieste, Italy

Sept 12, 2023

First Observational Campaigns of the Mapper of the IGM Spin Temperature (**MIST**)

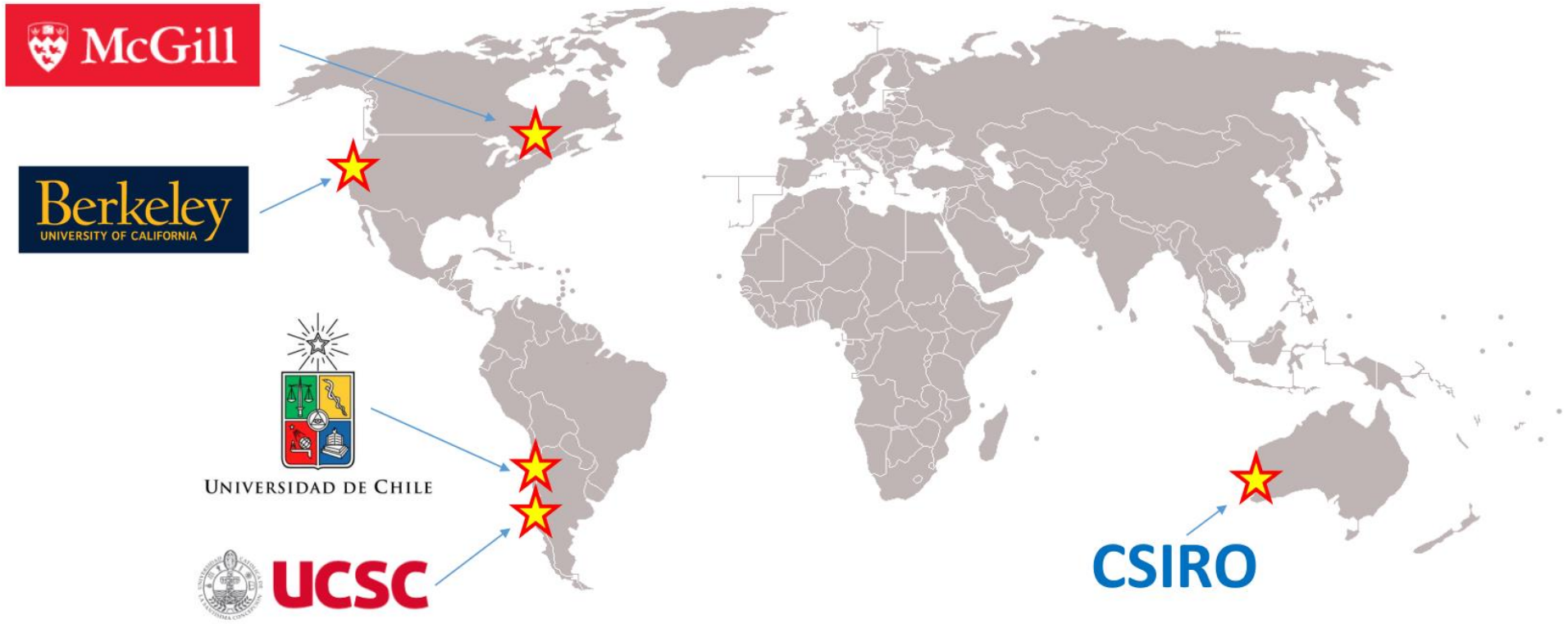
Ian Hendricksen

McGill

TSI Trottier Space Institute at McGill | Institut spatial Trottier de McGill

Mapper of the IGM Spin Temperature (MIST)

Experiment began in 2018



We acknowledge support from

Gobierno de Chile

UCSC

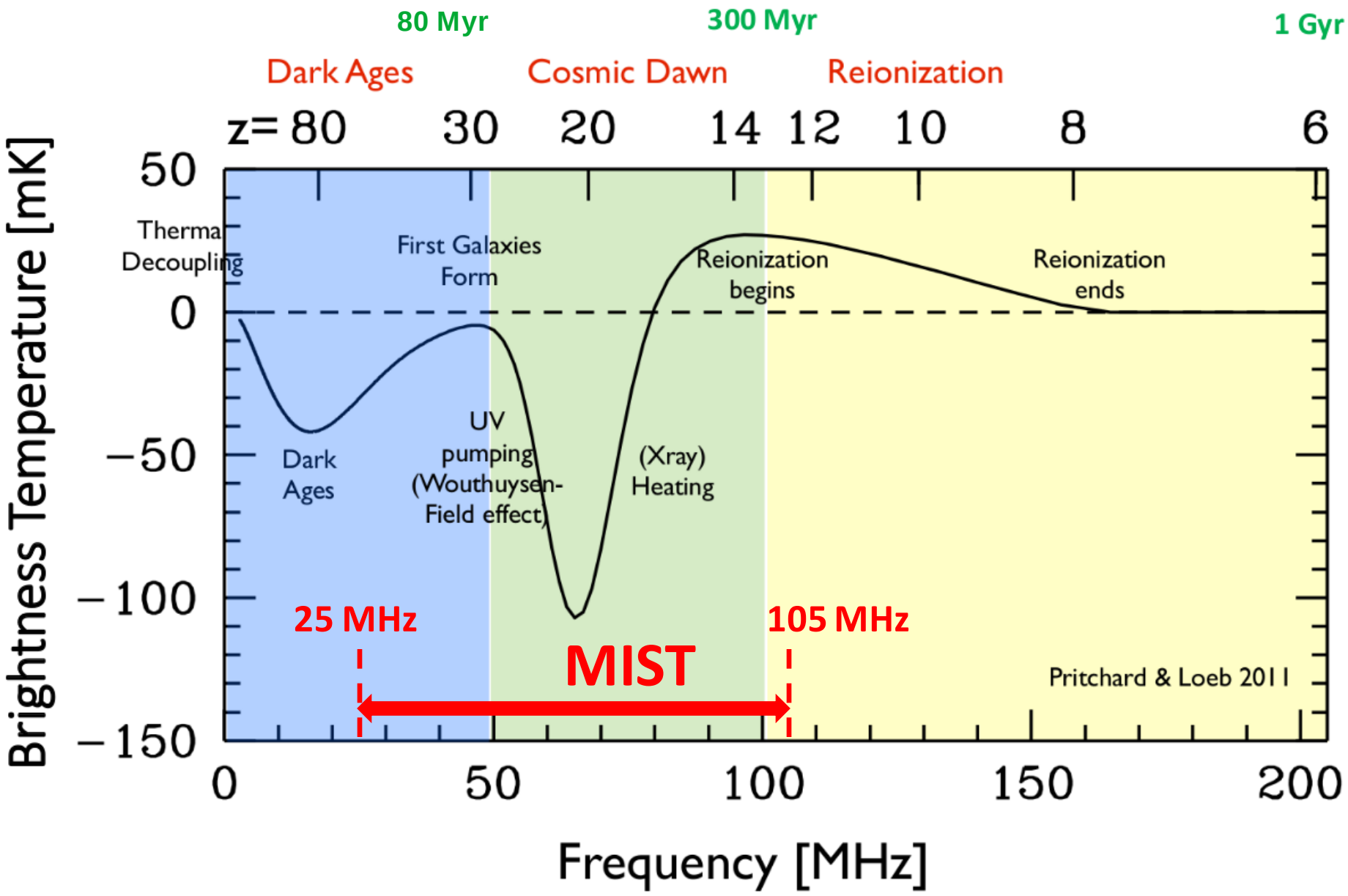
NSERC CRSNG

CSA ASC

Canadian Space Agency

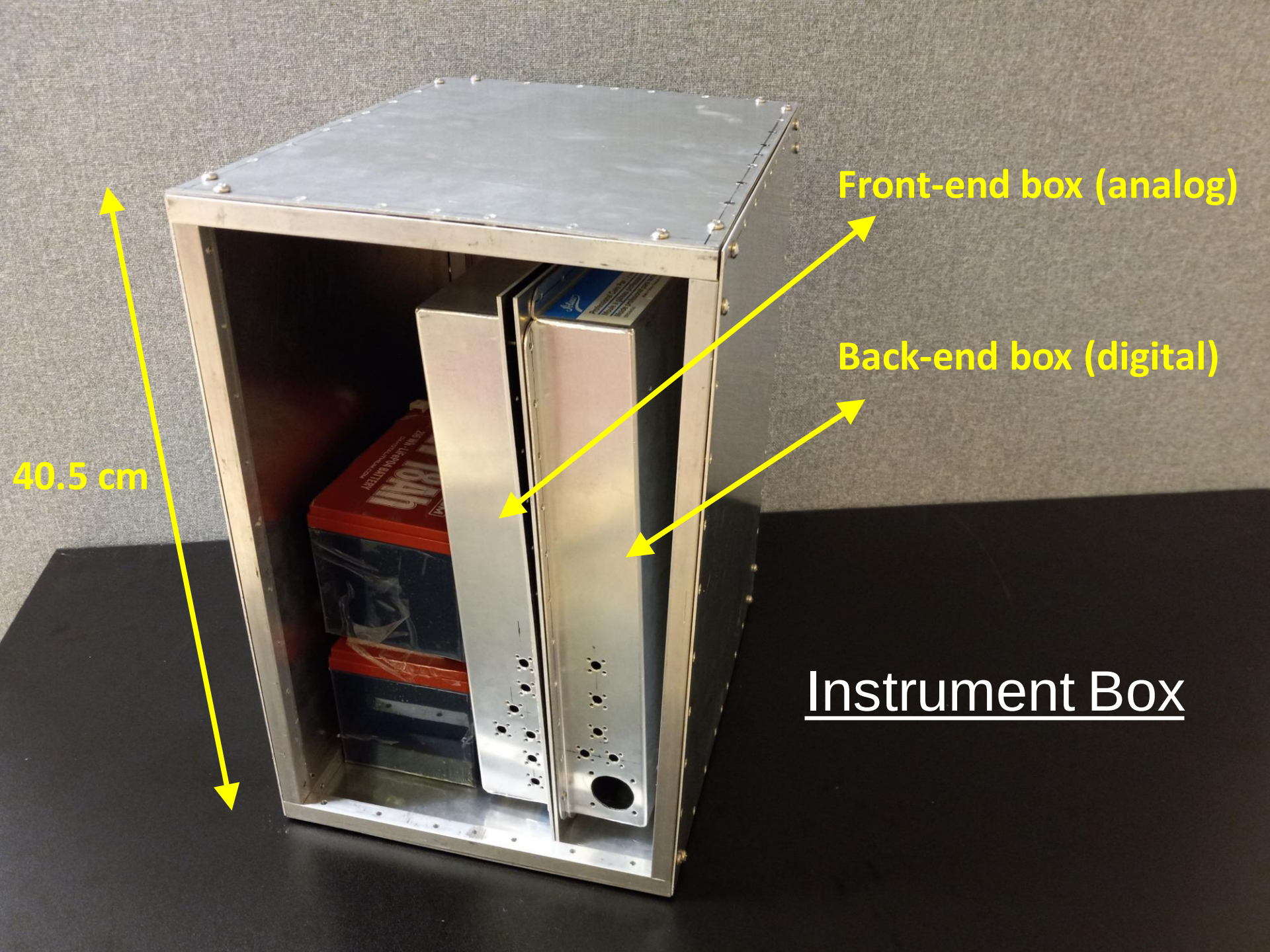
Frequency Range: 25-105 MHz

$$55.5 > z > 12.5$$



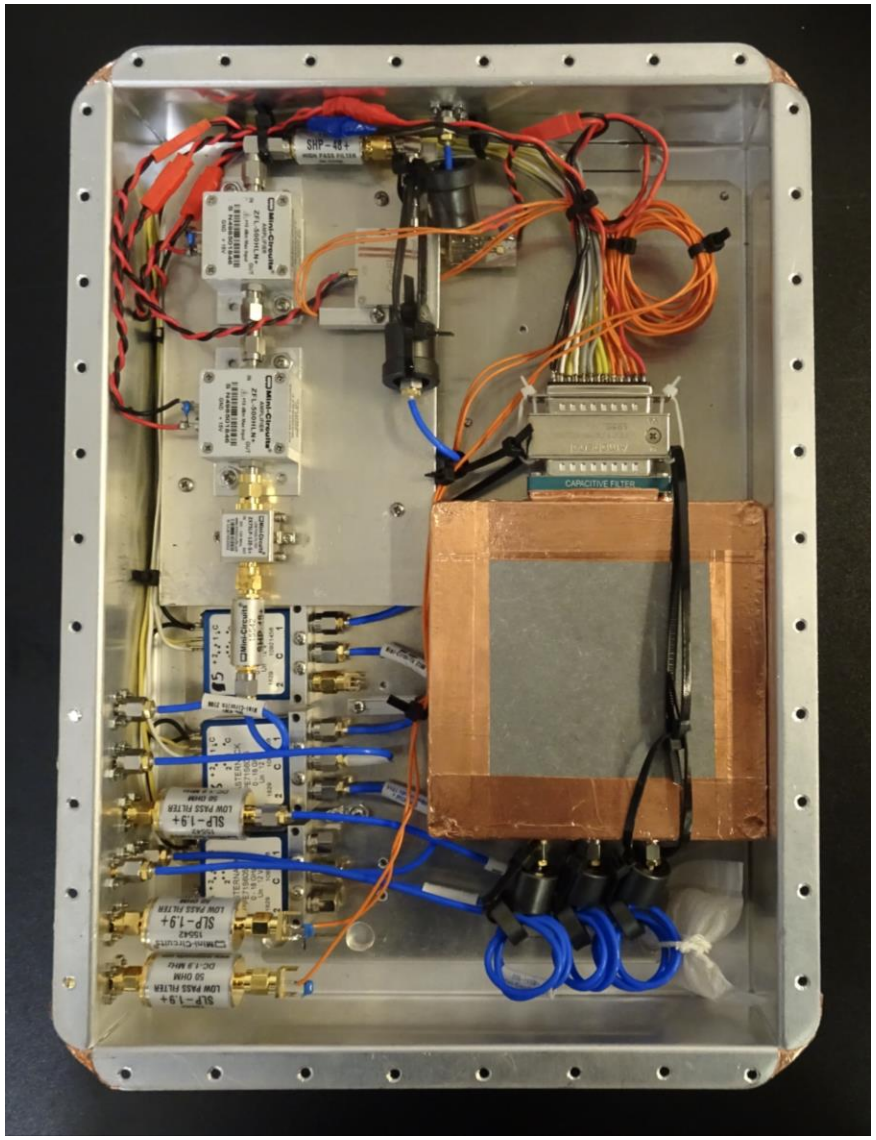
Two Instruments Built

- Single-antenna, **total-power radiometers**
- Frequency range **25-105 MHz**
- Wideband **dipole** antennas
- Antennas directly above ground, **without metal ground plane**
- Field measurements of **spectra** and **impedance** of **antenna**
- **Small, high portability** for deployment at remote locations
- Power consumption of **17 watts**
- Powered by **12 V batteries**

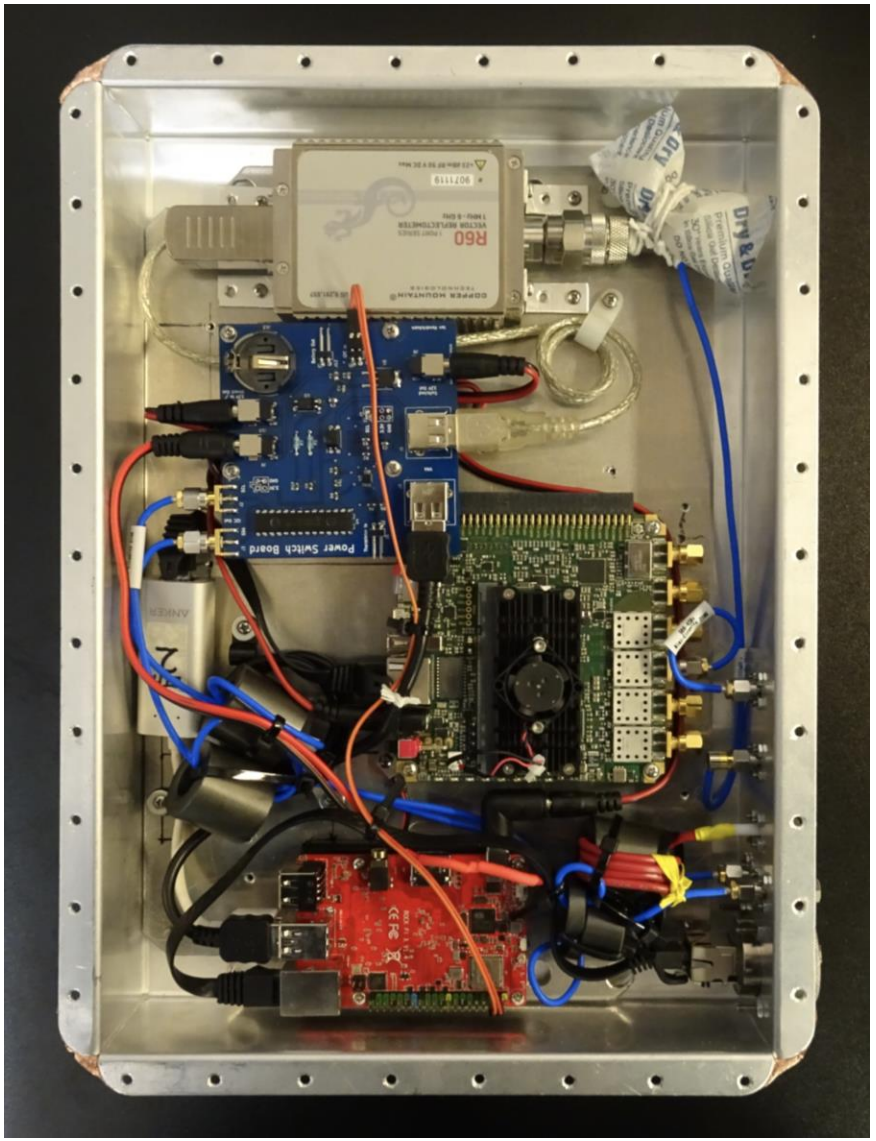

Front-end box (analog)
Back-end box (digital)
40.5 cm
Instrument Box

Electronics

Front-end box (analog)



Back-end box (digital)



Mapper of the IGM Spin Temperature (MIST): Instrument Overview

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Received XXXX; accepted XXXX

Check out our instrument paper on the arXiv!

ABSTRACT

Context. The observation of the global 21 cm signal produced by neutral hydrogen gas in the intergalactic medium (IGM) during the Dark Ages, Cosmic Dawn, and Epoch of Reionization requires measurements with extremely well-calibrated wideband radiometers.
Aims. We describe the design and characterization of the Mapper of the IGM Spin Temperature (MIST), which is a new ground-based, single-antenna, global 21 cm experiment.
Methods. The design of MIST was guided by the objectives of avoiding systematics from an antenna ground plane and cables around the antenna, as well as maximizing the instrument's on-sky efficiency and portability for operations at remote sites.
Results. We have built two MIST instruments, which observe in the range 25–105 MHz. For the 21 cm signal, this frequency range approximately corresponds to redshifts $55.5 > z > 12.5$, encompassing the Dark Ages and Cosmic Dawn. The MIST antenna is a horizontal blade dipole of 2.42 m in length, 60 cm in width, and 52 cm in height above the ground. This antenna operates without a metal ground plane. The instruments run on 12 V batteries and have a maximum power consumption of 17 W. The batteries and electronics are contained in a single receiver box located under the antenna. We present the characterization of the instruments using electromagnetic simulations and lab measurements. We also show sample sky measurements from recent observations at remote sites in California, Nevada, and the Canadian High Arctic. These measurements indicate that the instruments perform as expected. Detailed analyses of the sky measurements are left for future work.

Key words. methods: observational – galaxy: general – instrumentation: miscellaneous – Astronomical instrumentation, methods and techniques – Cosmology: observations, dark ages, reionization, first stars

arXiv:2309.02996

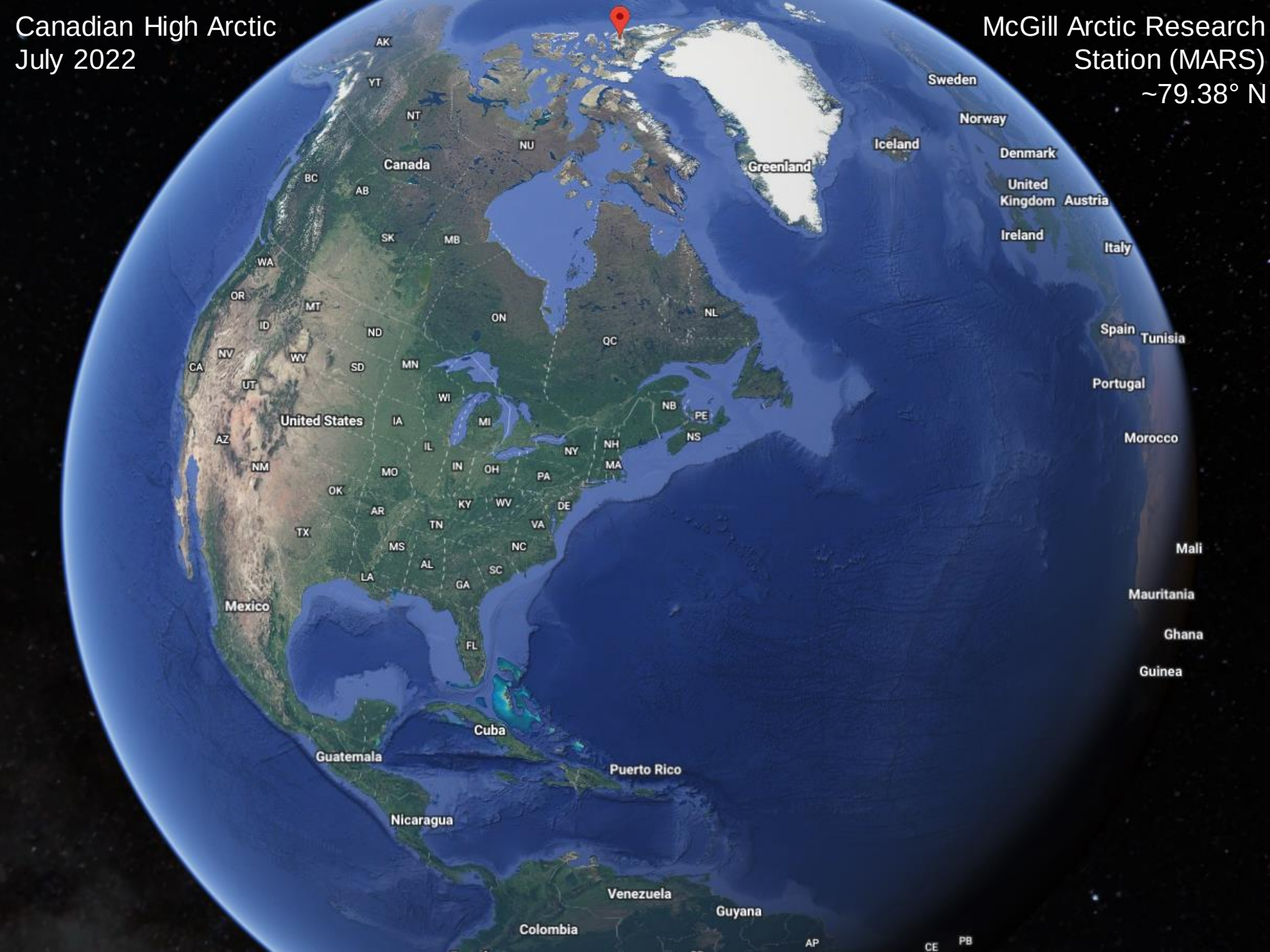
1. Introduction

The measurement of the 21 cm line from neutral hydrogen gas in the intergalactic medium (IGM) has been recognized as a promising way to map the evolution of the Universe during its reionization (EoR) have to be conducted at $\nu < 220$ MHz[1]. Several radio experiments are trying to detect this cosmological signal. They can be classified into those targetting the sky-averaged or global component, and antenna arrays focussing on spatial anisotropies. Ground-based global 21 cm experiments include

Field Measurements in 2022

California and Nevada Desert, May 2022

Death Valley


Canadian High Arctic
July 2022
McGill Arctic Research Station (MARS)
~79.38° N
AK
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OR
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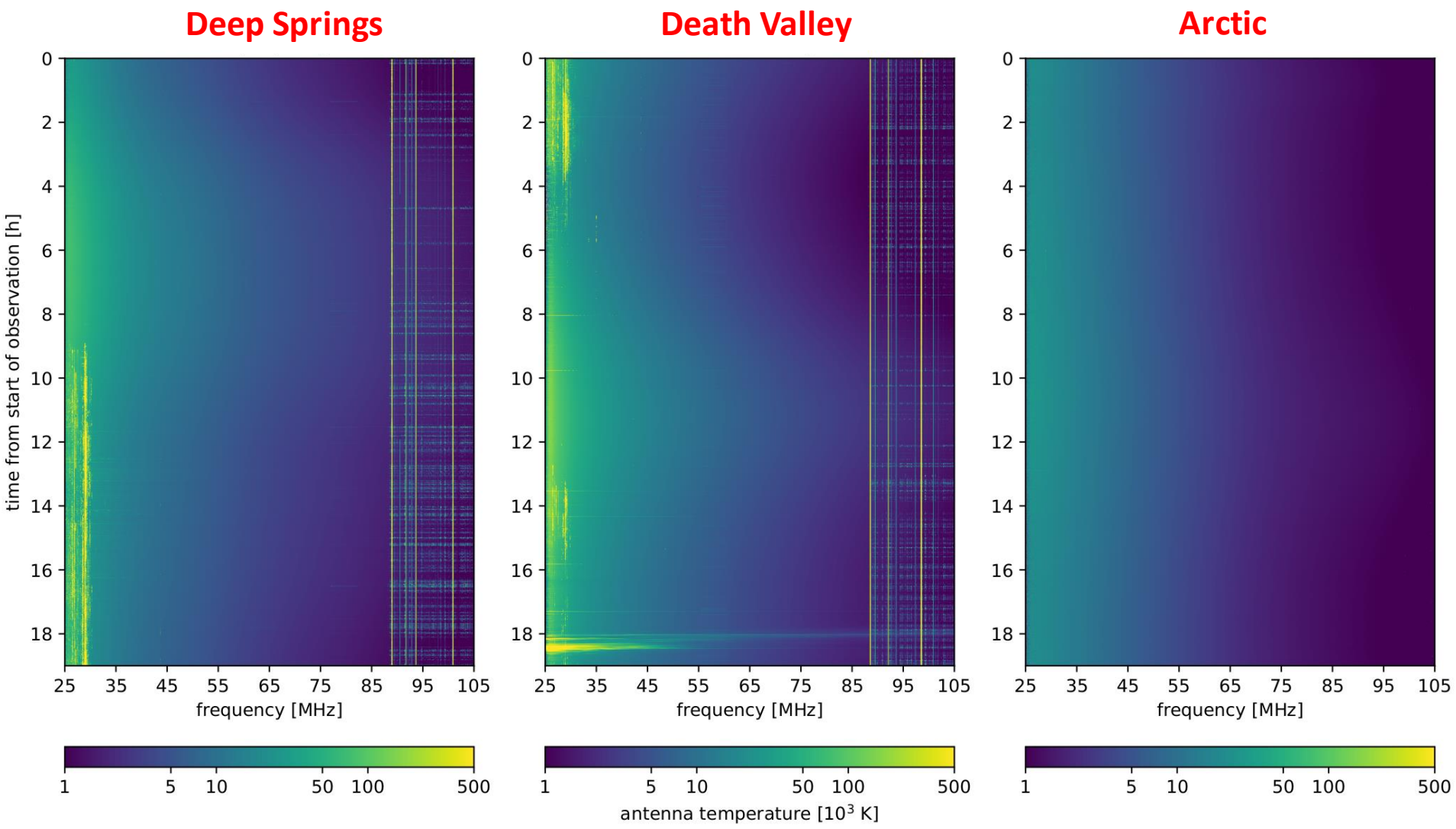
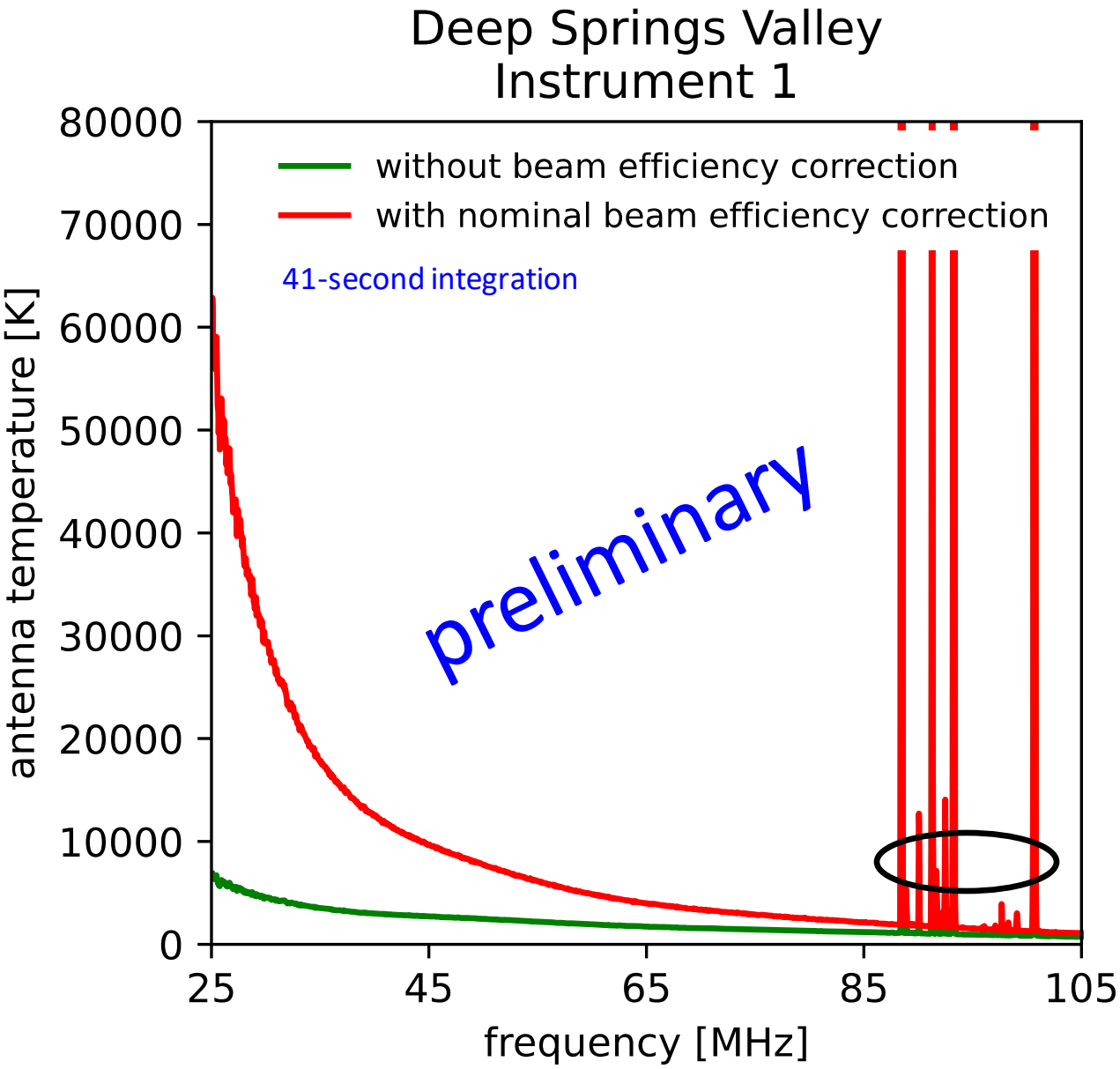
Puerto Rico
Nicaragua
Venezuela
Guyana
Colombia
Greenland
Iceland
Sweden
Norway
Denmark
United Kingdom
Austria
Ireland
Italy
Spain
Tunisia
Portugal
Morocco
Mali
Mauritania
Ghana
Guinea

Arctic

Antenna Temperature, 19 hours




Deep Springs Valley
Instrument 1
without beam efficiency correction
with nominal beam efficiency correction
41-second integration
preliminary
antenna temperature [K]
frequency [MHz]
80000
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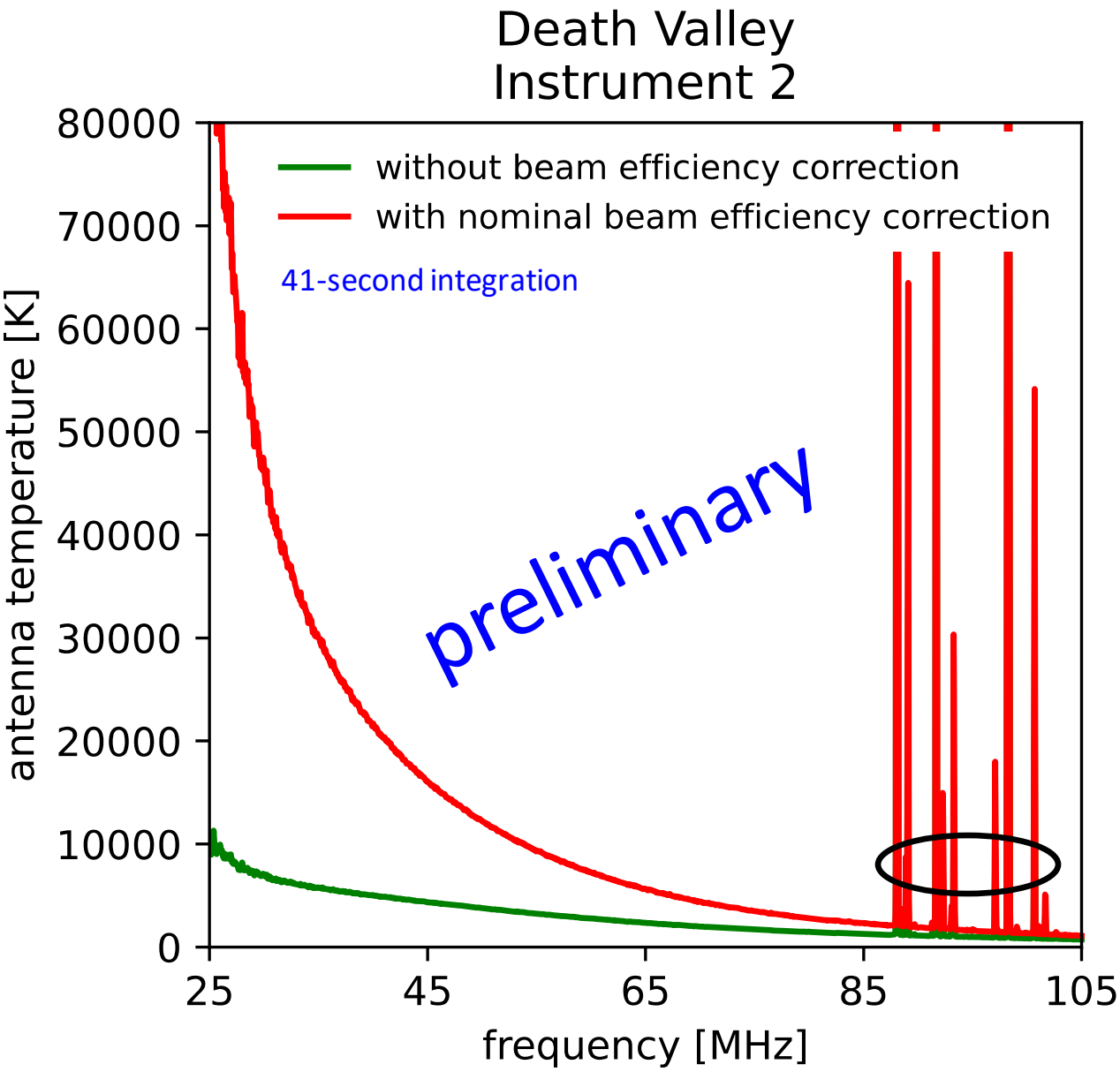
Death Valley
Instrument 2
without beam efficiency correction
with nominal beam efficiency correction
41-second integration
preliminary
antenna temperature [K]
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10000
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25
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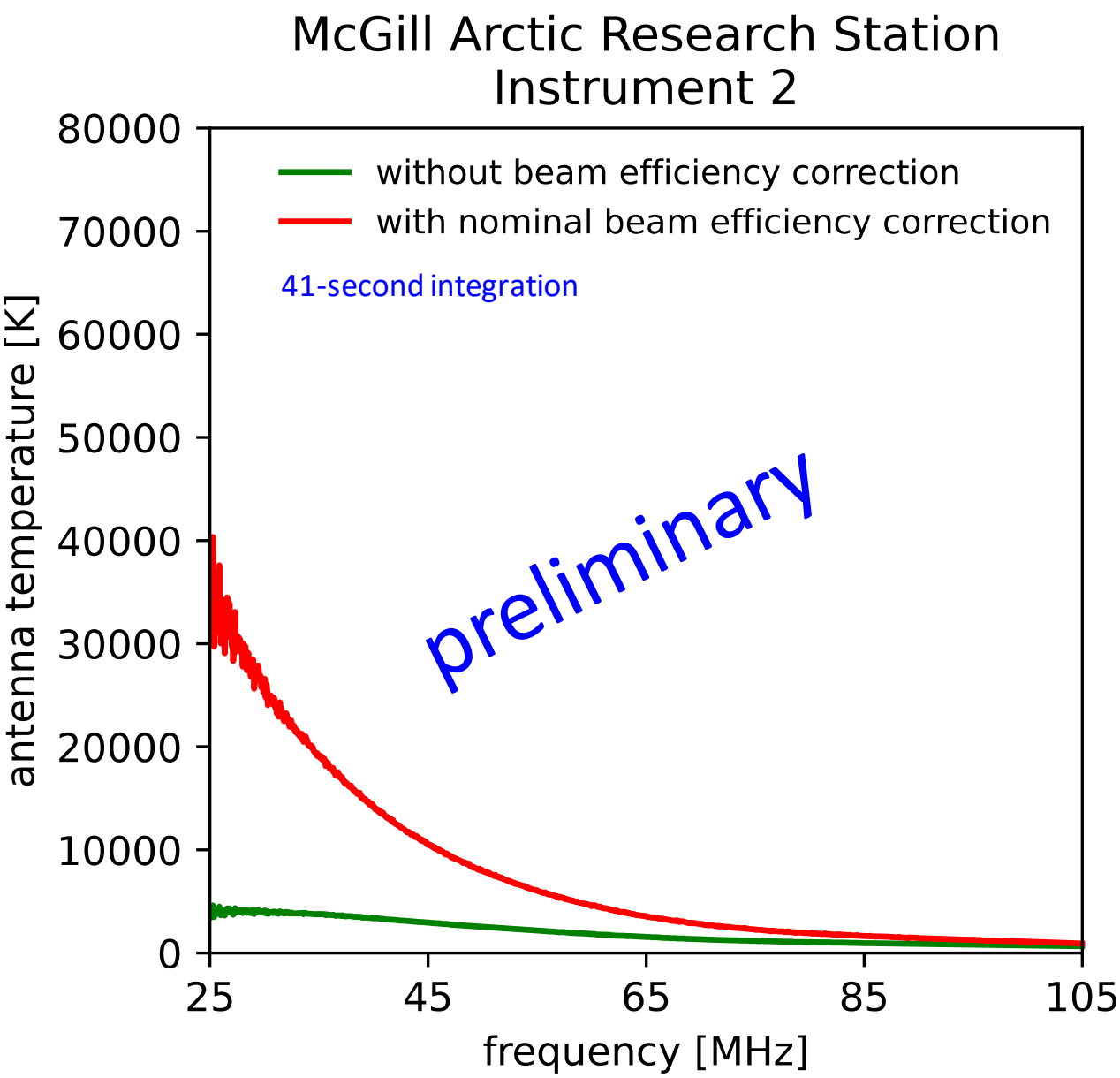
105
frequency [MHz]


McGill Arctic Research Station
Instrument 2
without beam efficiency correction
with nominal beam efficiency correction
41-second integration
preliminary
antenna temperature [K]
frequency [MHz]
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70000
60000
50000
40000
30000
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10000
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25
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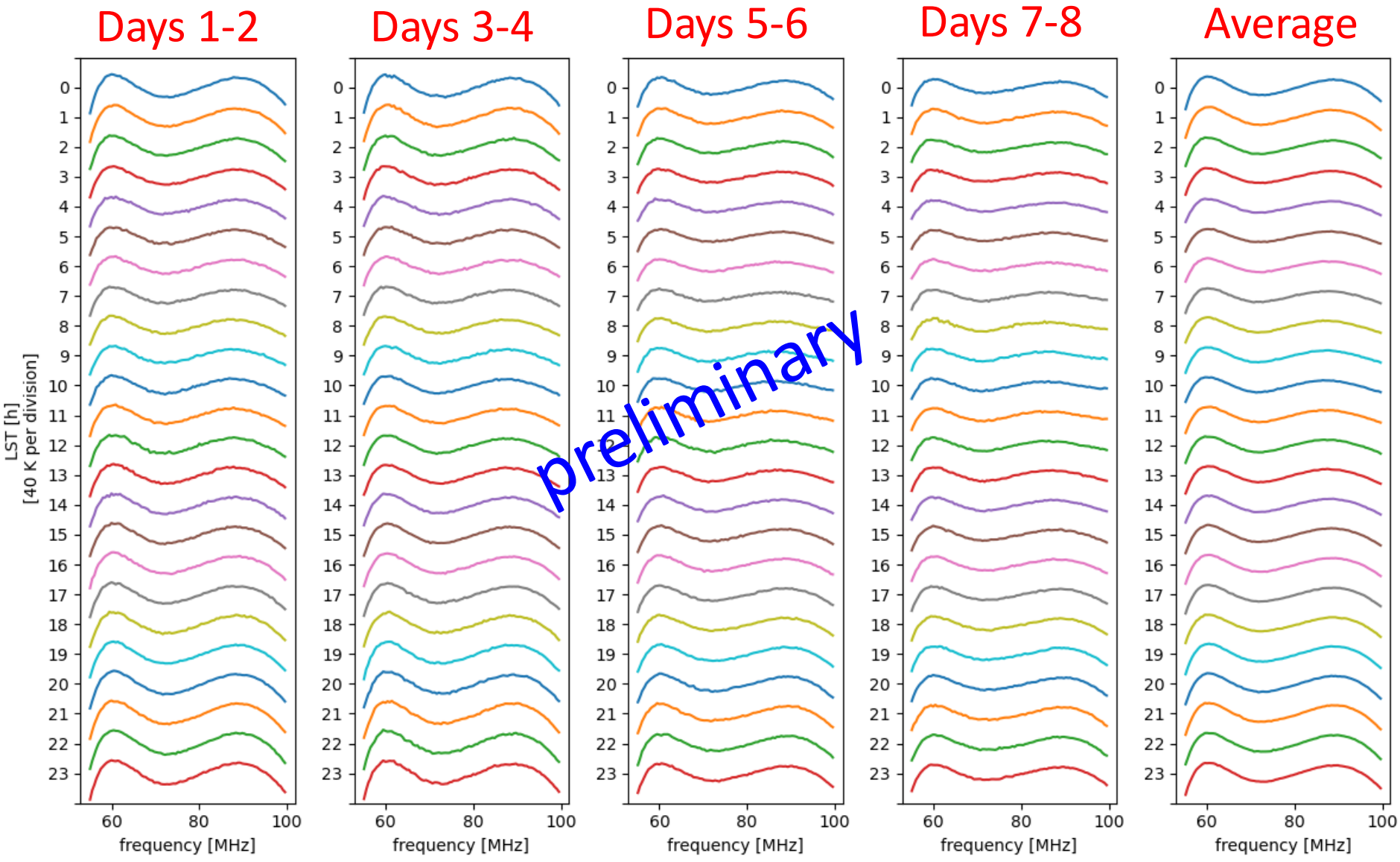
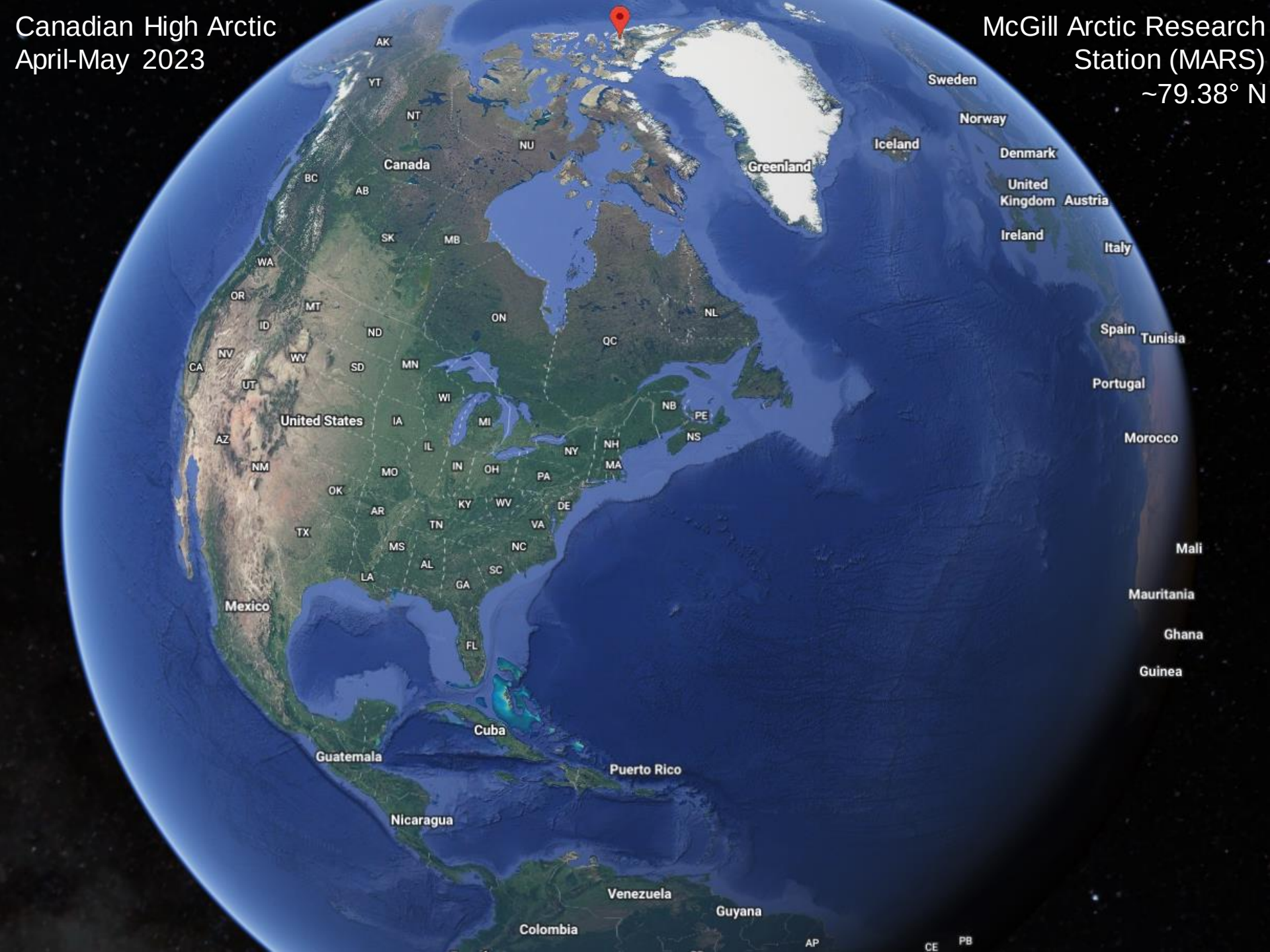
105

Data from Arctic: Residuals for 4-term Polynomial Scaled by Power Law



Field Measurements in 2023


Canadian High Arctic
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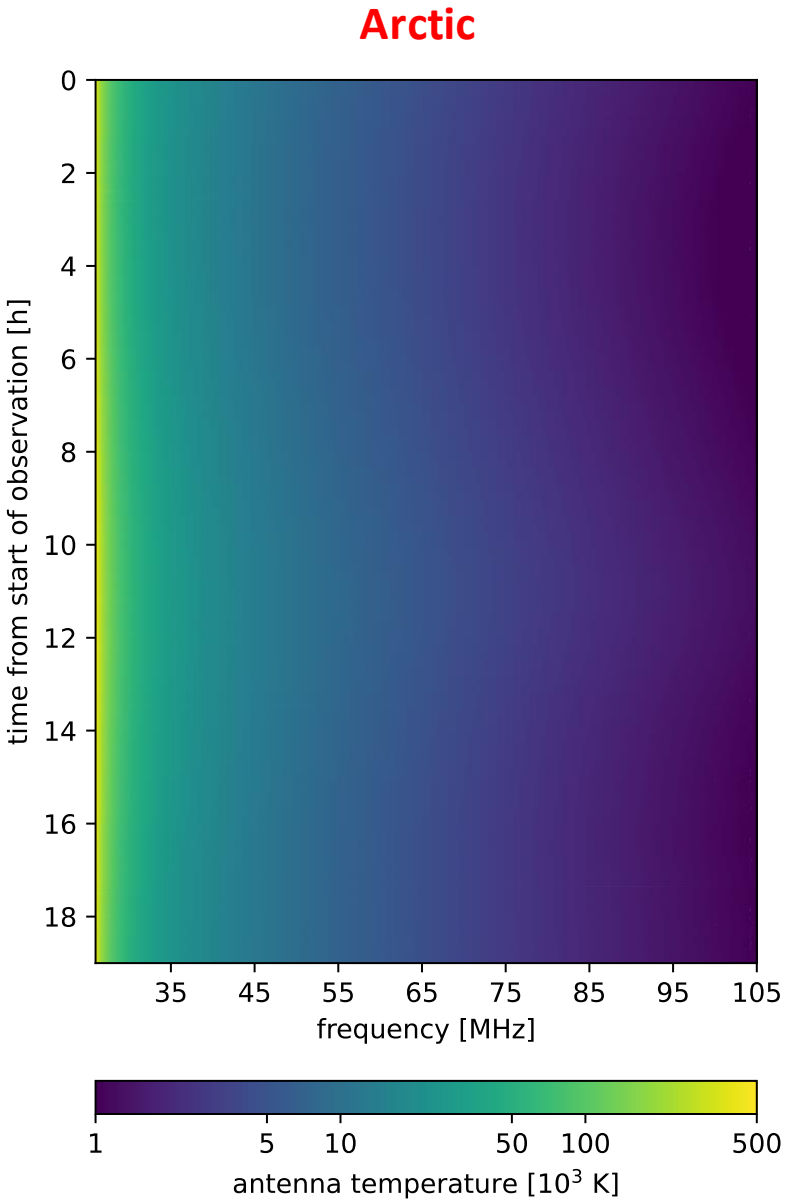
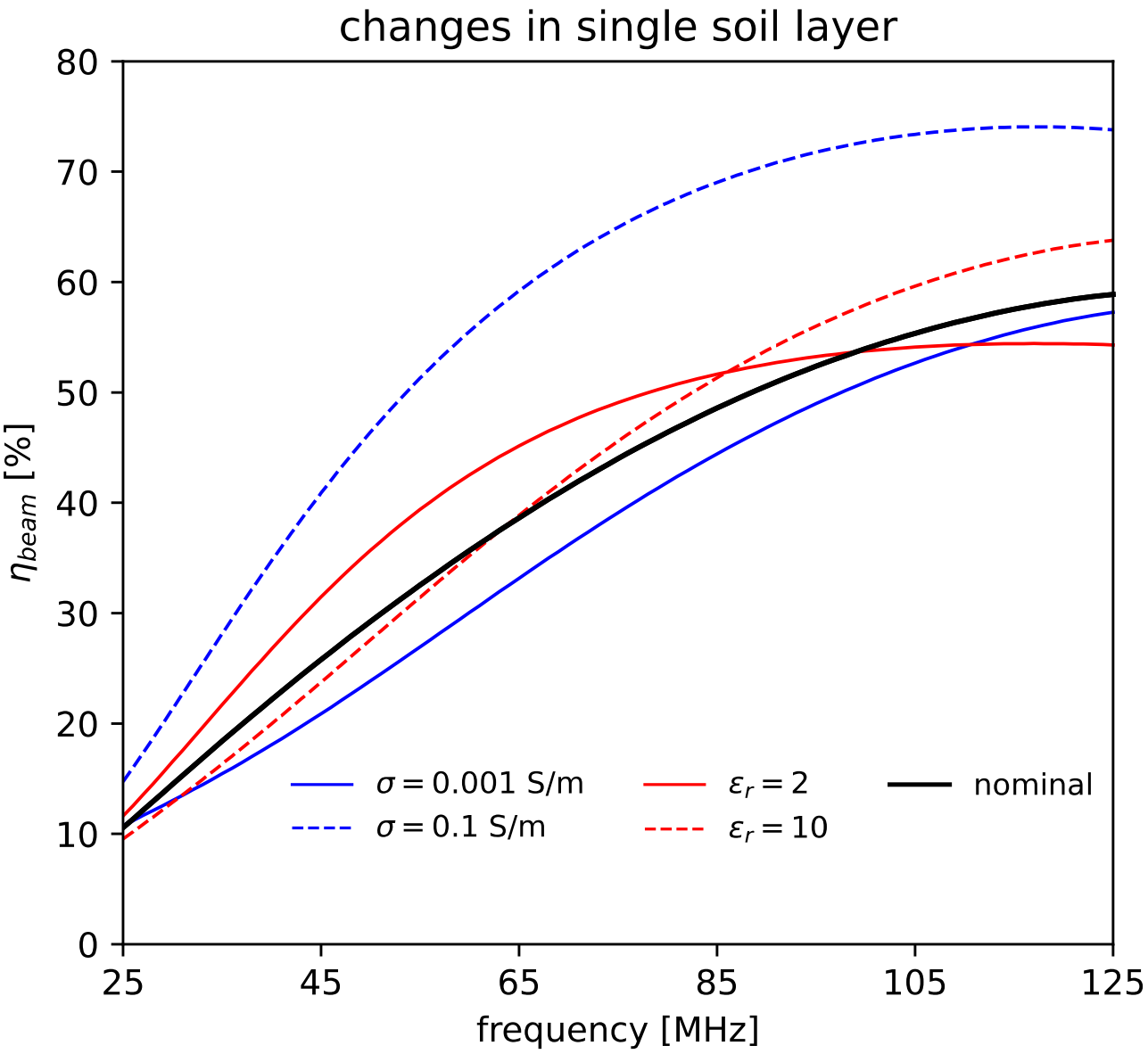
Mexico
Cuba
Guatemala
Puerto Rico
Nicaragua
Venezuela
Guyana
Colombia
Greenland
Iceland
Sweden
Norway
Denmark
United Kingdom
Ireland
Austria
Italy
Spain
Tunisia
Portugal
Morocco
Mali
Mauritania
Ghana
Guinea

Glaciologists and Cosmologists

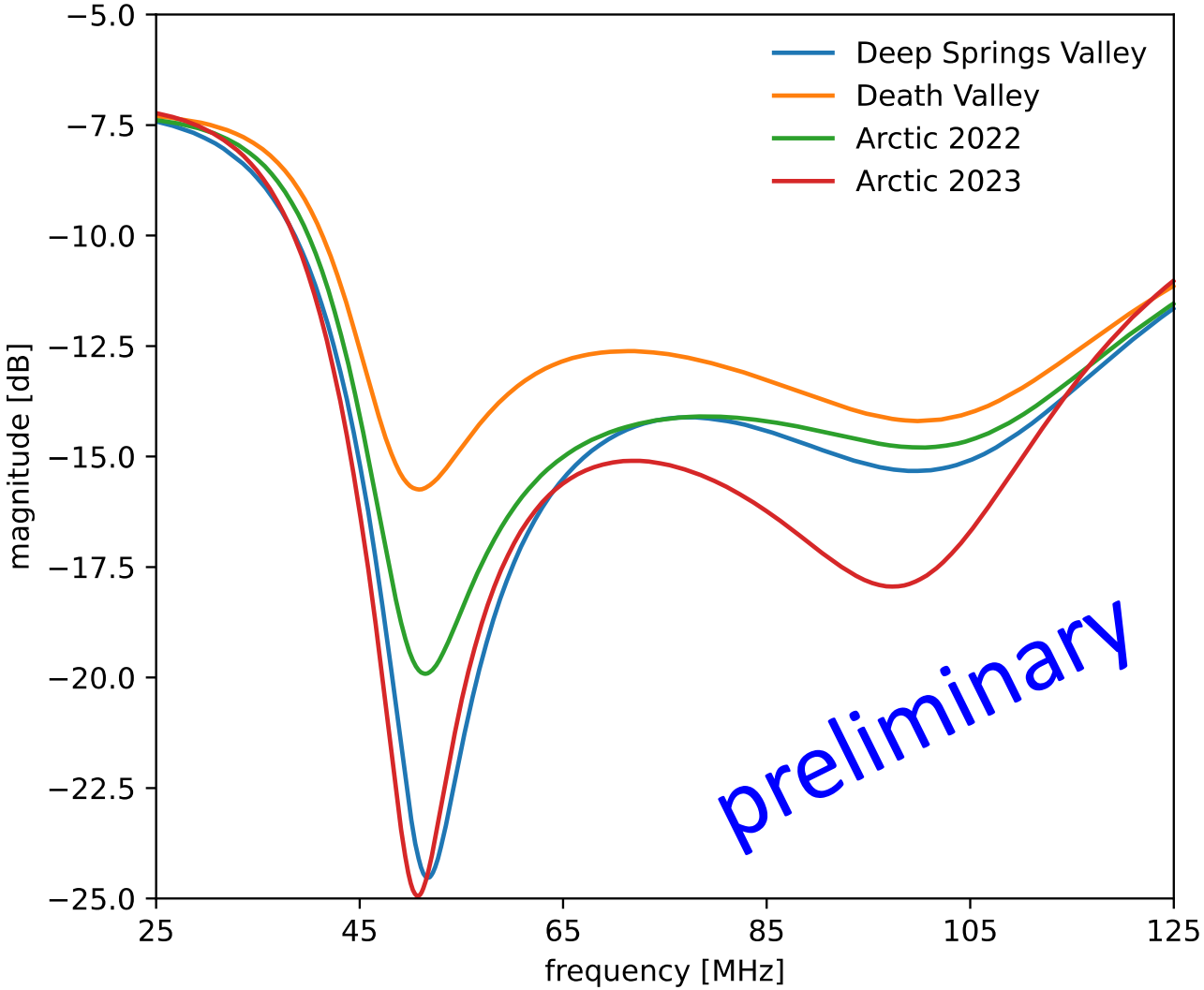
Antenna Temperature, 19 hours



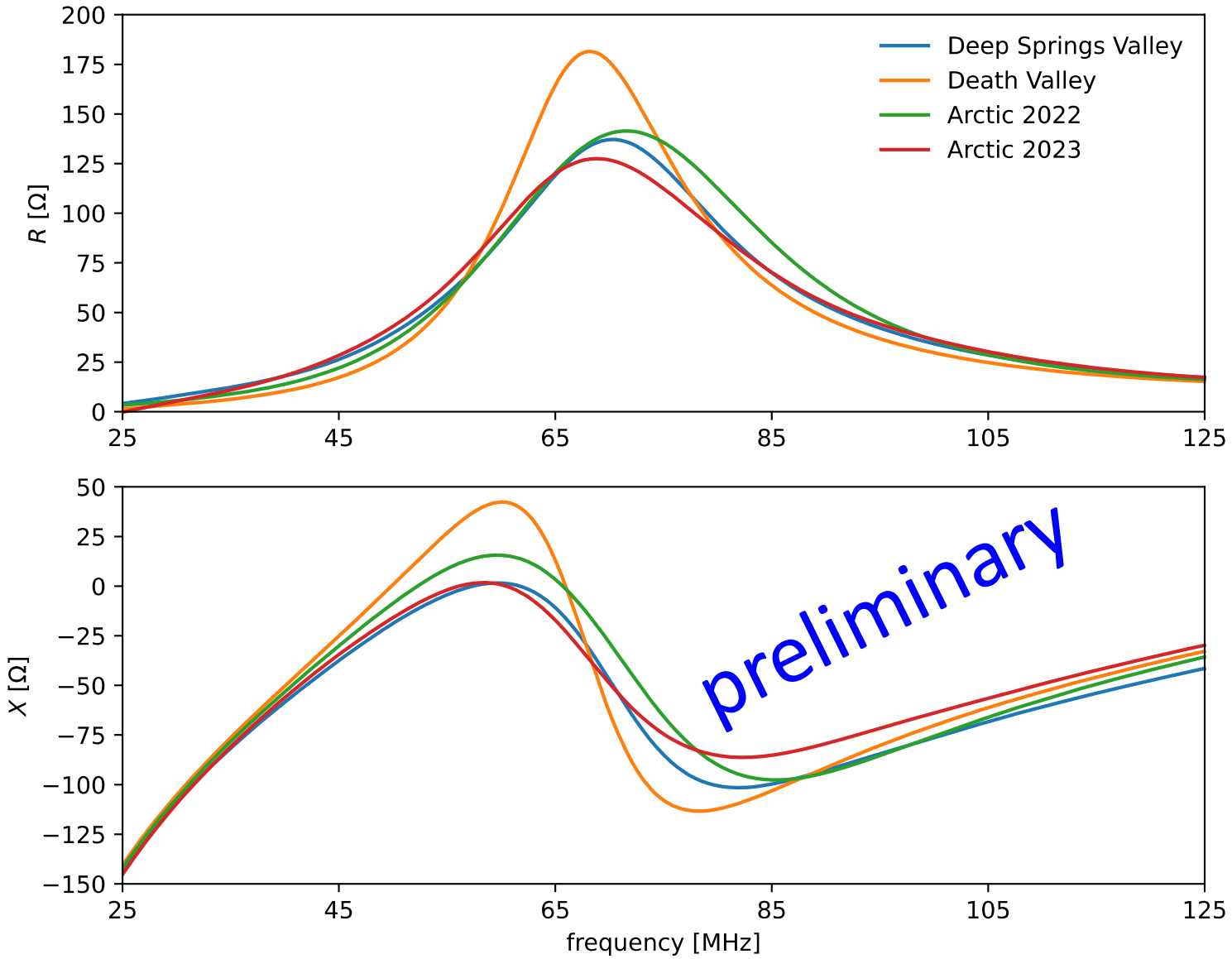
Beam Efficiency (1 - ground loss fraction)



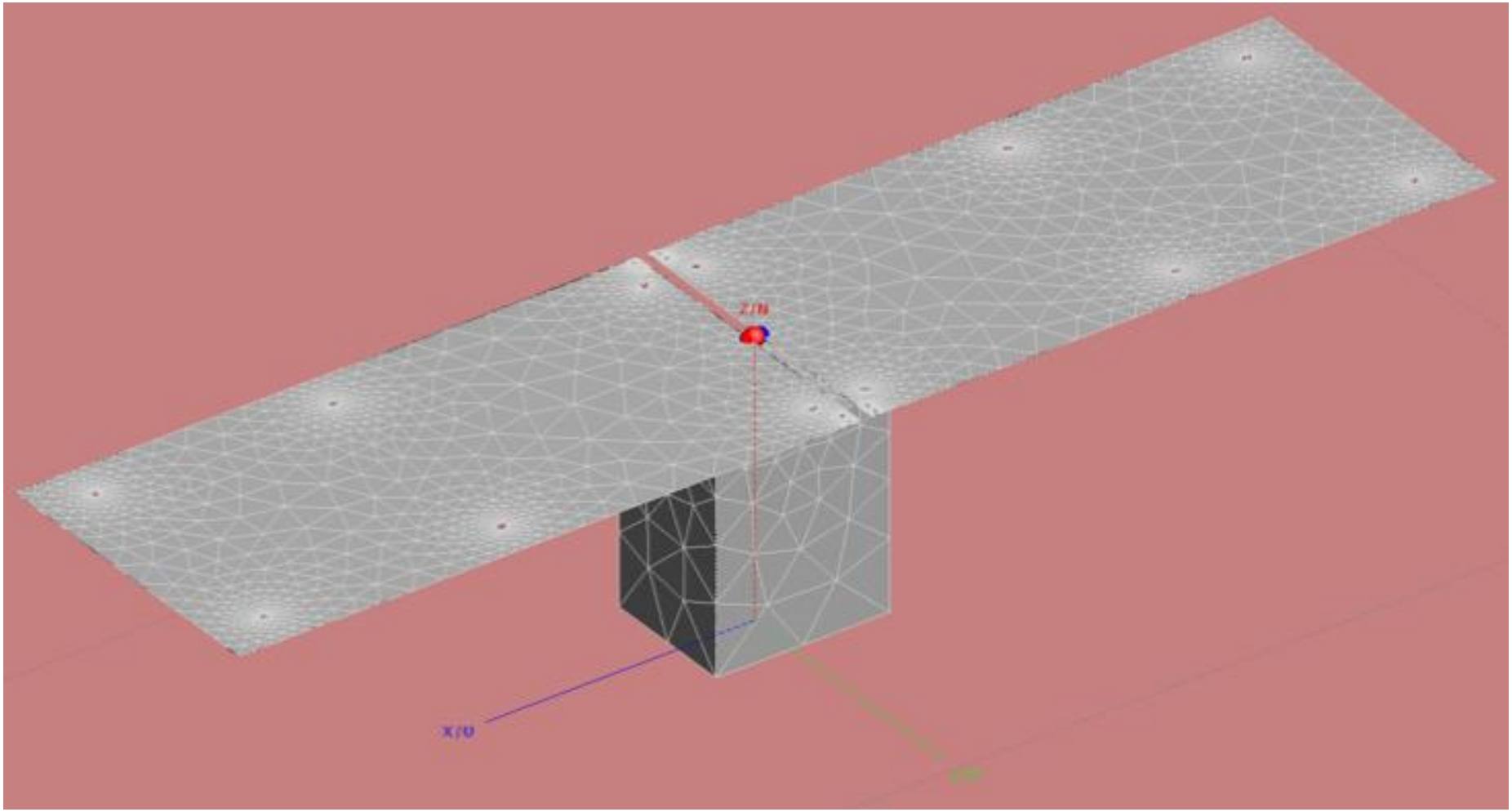
Antenna Reflection Coefficient



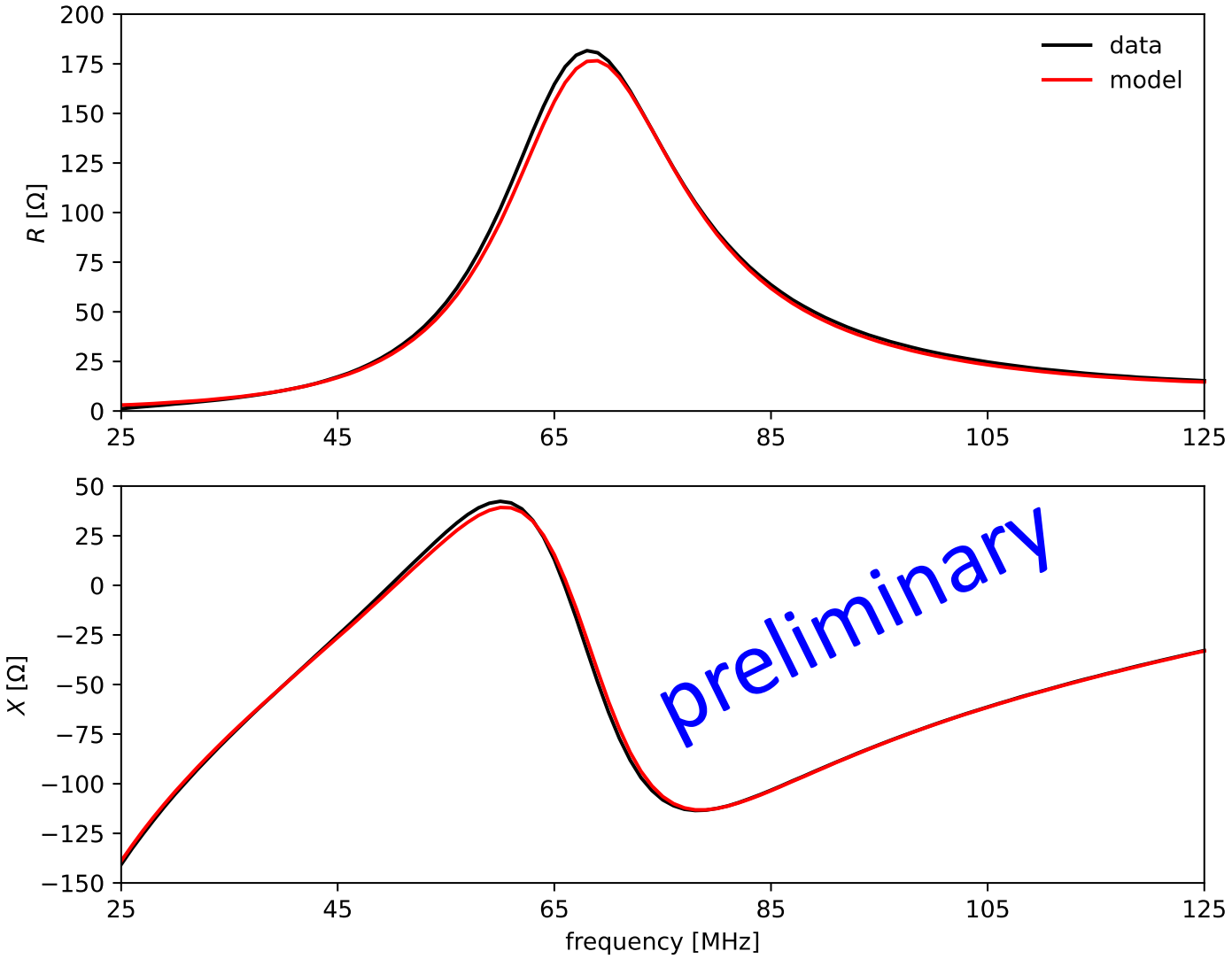
Antenna Impedance



EM Simulations



Fitting Models to Impedance Measurements



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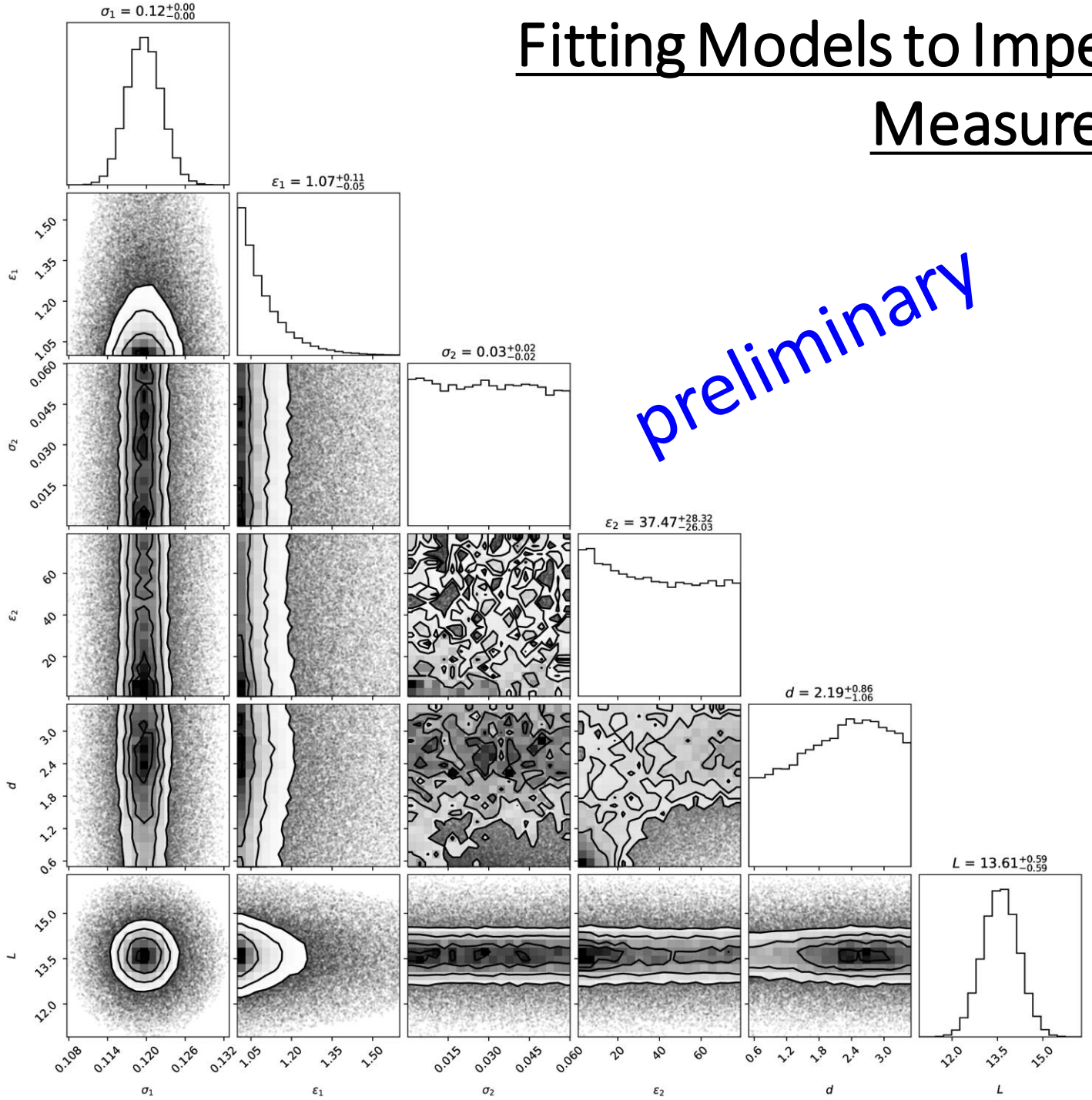

preliminary

Ground Penetrating Radar (GPR) Measurements

100 m x 100 m area centered at the MIST antenna
Area was swept by pulling GPR with skidoo

Common mid-point (CMP) measurements also conducted

Summary

- MIST **working toward detection of Global 21-cm signal** from the early Universe.
- Measuring the sky **down to 25 MHz, into the Dark Ages** frequencies.
- Data sets already available to study the **astrophysical foreground**.
- Making **progress on the data analysis**. Core of the work is on the **instrumental calibration**.
- Characterization of the **soil is critical**. **Using different techniques** for this purpose.
- We hope to present **astrophysical results soon**!
- Check out **instrument paper** on arXiv: 2309.02996

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