CMB S4 Status Update

AMLIGHT SA3CC 2023, August 1, 2023
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for CMB S4 collaboration

CMB-S4

A few notes

- This presentation contains the work of many people
- All of the material is from others 😄
- I am not myself a member of CMB S4
- I will do my best to represent the project here, but specific questions are best directed to Eli Dart (ESNet) and Julian Borrill (NERSC)
- Thank you for the opportunity to present CMB-S4 to you today!

CMB-S4

- 459 members
- 115 institutions
- 21 countries

U.S. DEPARTMENT OF ENERGY | Office of Science

NSF

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Science Goals

CMB-S4 will dramatically push forward our understanding of the history, evolution, and contents of the Universe by achieving four Science Goals:

GOAL 1: Test models of inflation by measuring or putting upper limits on r, the ratio of tensor fluctuations to scalar fluctuations.

GOAL 2: Determine the role of light relic particles in fundamental physics, and in the structure and evolution of the Universe.

GOAL 3: Measure the emergence of galaxy clusters as we know them today. Quantify the formation and evolution of the clusters and the intracluster medium during this crucial period in galaxy formation.

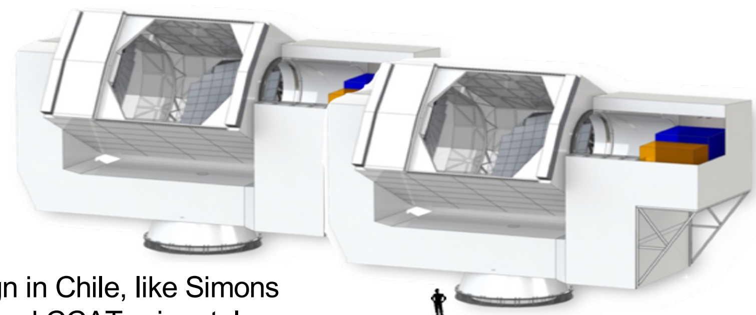
GOAL 4: Explore the millimeter-wave transient sky. Use the rate of mm-wave Gamma-Ray Bursts (GRB) to constrain GRB mechanisms. Provide mm-wave variability and polarization measurements for stars and active galactic nuclei.

(Ref. Program Level Requirements, CMBS4-doc-671)

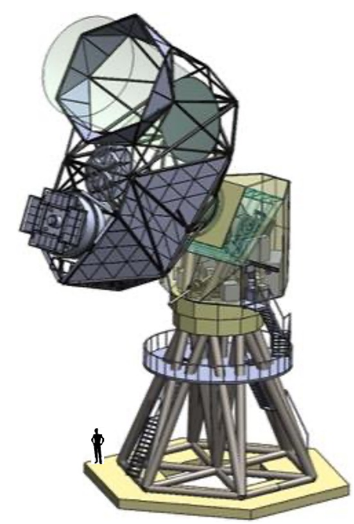
Experiment Design

Flowdown from the science goals leads to an experiment with:

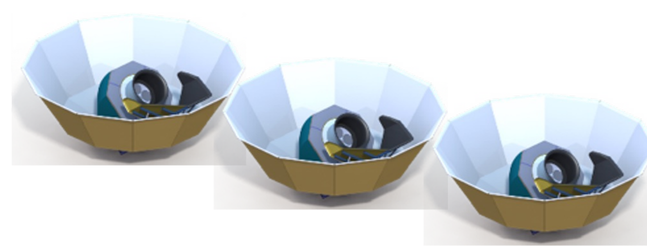
- A deep-wide survey targeting ~70% of sky from Chile using **2 x 6m telescopes** with **275,992 detectors** over **6 frequency bands**.
- An ultra-deep survey targeting ~3% of sky from the South Pole using **9 x 0.5m telescopes** with **90,816 detectors** over **8 frequency bands** and **1 x 5m telescope** with **129,024 detectors** over **7 frequency bands**.



6m C-D design in Chile, like Simons Observatory and CCAT-prime telescopes



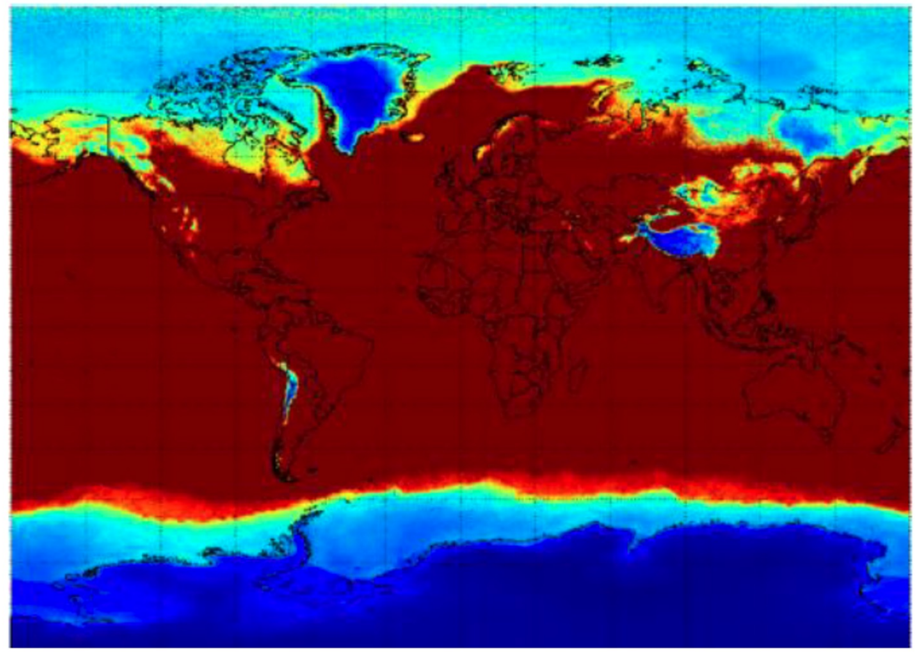
5m TMA design with monolithic mirrors and boresight rotation at South Pole



9 x 0.6 m small telescopes (3 per cryostat/mount), heritage from BICEP Array & Simons Observatory

Sites

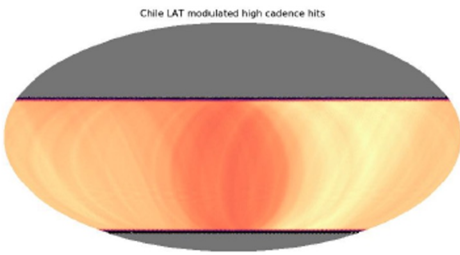
- Ground-based CMB observations are limited by the atmosphere: we need high, dry, sites.
- The South Pole and Chilean Atacama are the highest, driest sites.
- The US CMB community has a long history of working at both, and significant infrastructure is already in place for CMB-S4 precursors (South Pole Observatory; Simons Observatory & CCAT-prime)



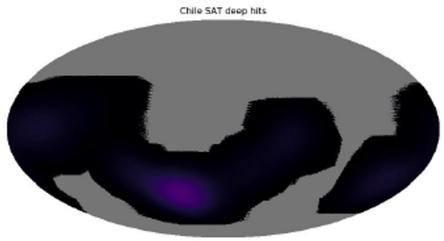
Mean precipitable water vapor across the globe. Candidate sites (dark blue) are the South Pole, Chilean and Argentinian Atacama Desert, Tibetan Plateau & Greenland.

Survey Strategies

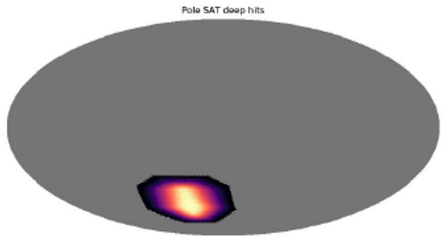
- CMB-S4 is unique in having *two* exceptional observing sites available.
- The biggest difference between the sites is in the types of sky surveys their latitudes can support.
  - Wide-area surveys can only be performed from the Atacama.
  - Compact ultra-deep surveys can only be performed from the South Pole.



Chile wide survey hitmap



Chile deep survey hitmap



South Pole ultra-deep survey hitmap

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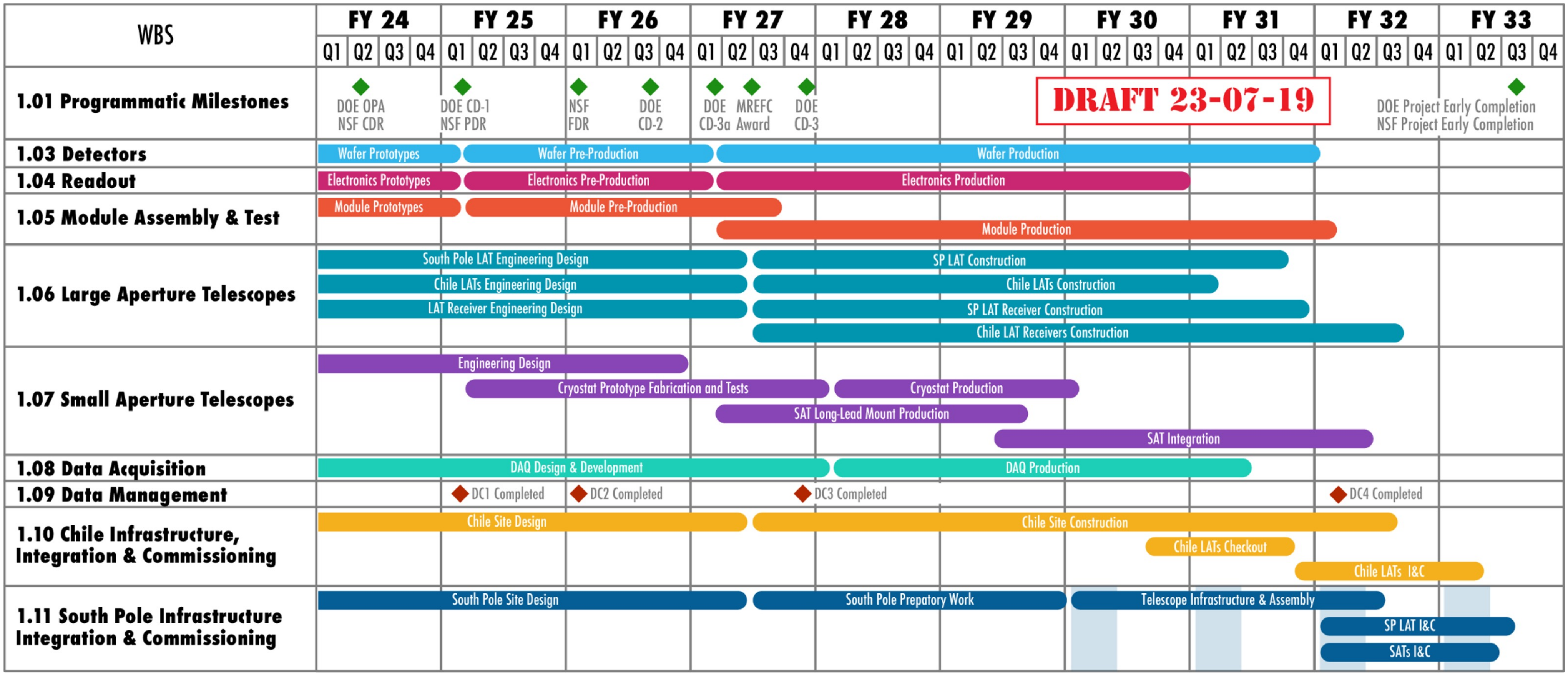
Current CMB-S4 Project Timeline



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Prototyping: Data Distribution

- NERSC's Modern Research Data Portal:
  - Tool based on the Globus platform
  - Well documented, simple customization/initialization
  - Current interest from other collaborations (e.g. LZ)
  - Used by the LSST-DESC collaboration, among others

- Prototype CMB-S4 data portal
  - https://data.cmb-s4.org/
  - Preliminary data distribution service for Data Challenge 1

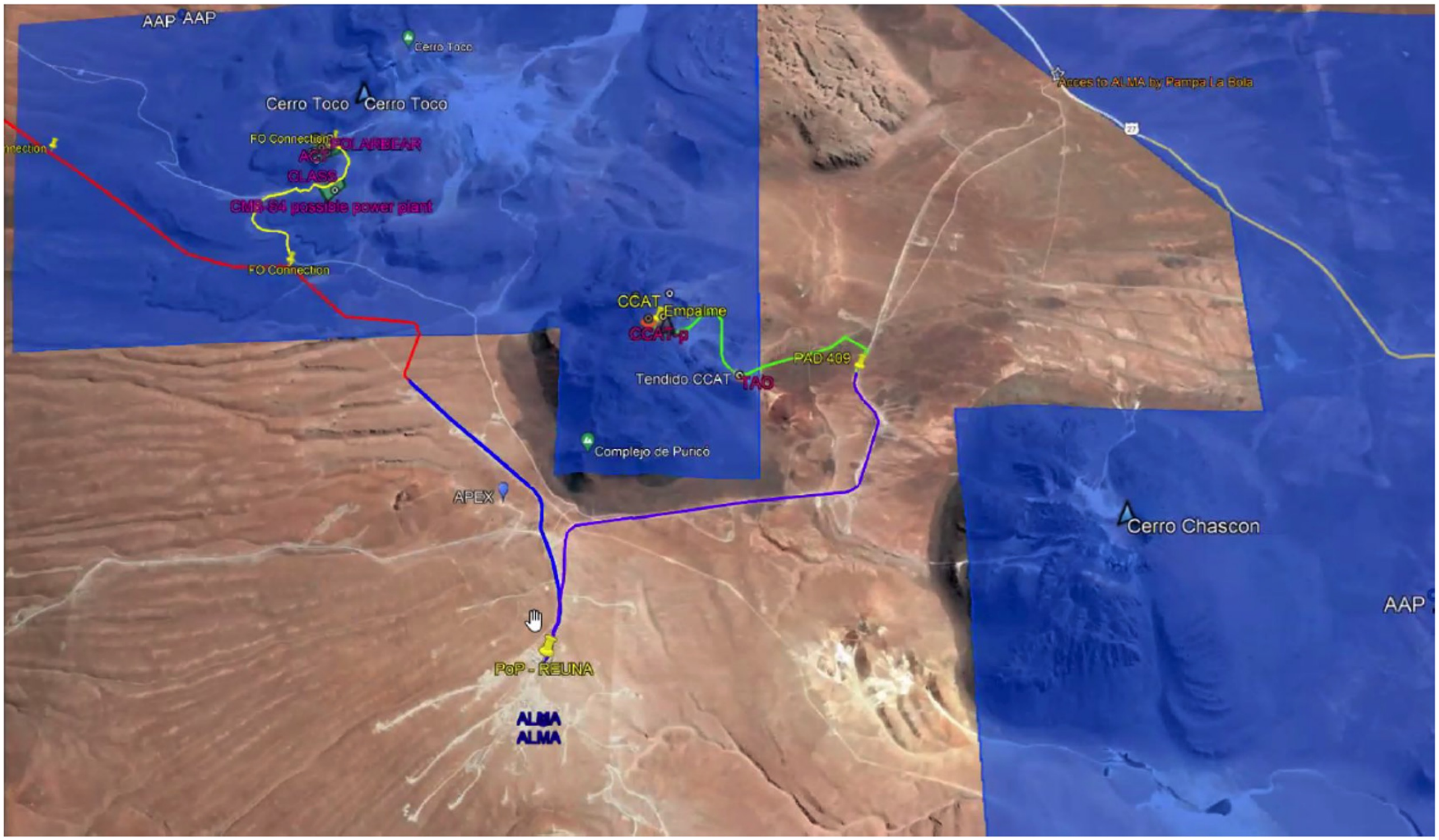
CMB-S4 Atacama Data

- Atacama steady state data rate ~1 Gbps (up to ~5Gbps in catch-up mode)
- Unlike SO, CMB-S4 will not do its initial data processing on site but instead stream the data back to the US to process.
  - Quick-look maps for data quality checks and transient detections
  - Goal is to issue transient alerts fast enough to allow follow-up observations
  - Current requirement is ~day, plan is ~hours (possibly ~minutes)
- Data processing options include national computing resources (eg. NERSC), dedicated project hardware (eg. US cluster), and - ideally - FABRIC in-network computing.

Cerro Toco Fiber Paths

Fiber optic connection being built from REUNA at ALMA to Simons Obs. and CMB-S4

- Currently being sited in collaboration with Simons
- Collaboration with REUNA on services design



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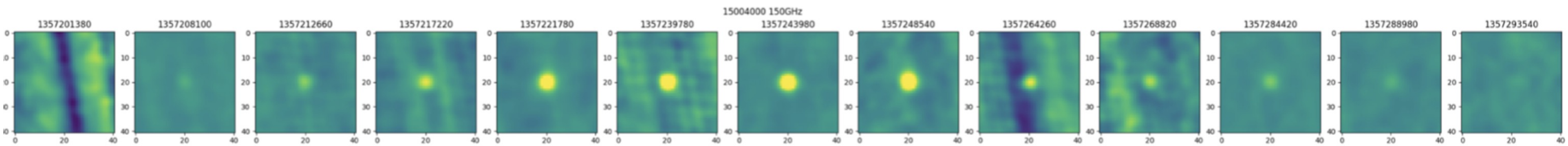
CMB-S4 & FABRIC



Successive images of a simulated mm wave transient showing growth and decay
-- credit Felipe Menanteau

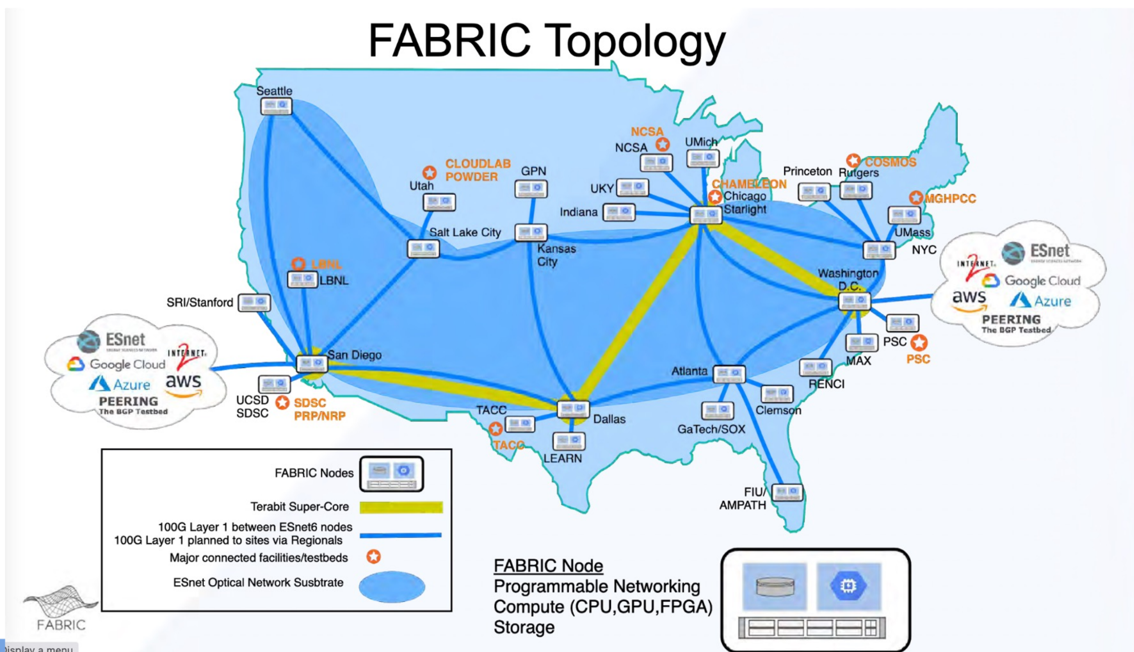
Science Motivation: "open the window for mm-wave transient science"

Detection need: "prompt" detection/alerting of mm transients, allowing for follow-up observation.

Technical need: Robust computing environment where transient-related processing occurs promptly every day we observe.

What is FABRIC

- A nation-wide programmable network with compute and storage at each node.
- Run computationally intensive programs & maintain information in the network.
- Integrate processing rersources CPU, GPUs, etc inside the network



Initial FABRIC topology (lef).

The topology has since expanded to include additional sites such as CERN and integrate NSF resources such as Chameleon.

A proposal to NSF seeks to maintain a topology as production infrastructure.

See: https://fabric-testbed.net

Experience with FABRIC Infrastructure

- Diverse collection of nodes and sites will provides a pool of available nodes with high ensemble reliability.
- FABRIC primitives provide the basis for software defined infrastructure.
- We use the distributed nodes to model our distributed deployment.
  - E.g FIU site represents Chilean Observatory, we compute on distributed nodes to model high availability.
- We demonstrated integration w/ tools of production computing
  - Containers
  - HTCondor
  - File transfer
  - Reproducible
  - Security boundaries.
  - Inflate/Deflate Slice - compute system (SDI)
- More information at https://zenodo.org/record/7971930