KOSMIC: K-band VLBI Observations with Improved Scheduling and Ionospheric Corrections

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KOSMIC: K-band VLBI Observations with Improved Scheduling and Ionospheric Corrections

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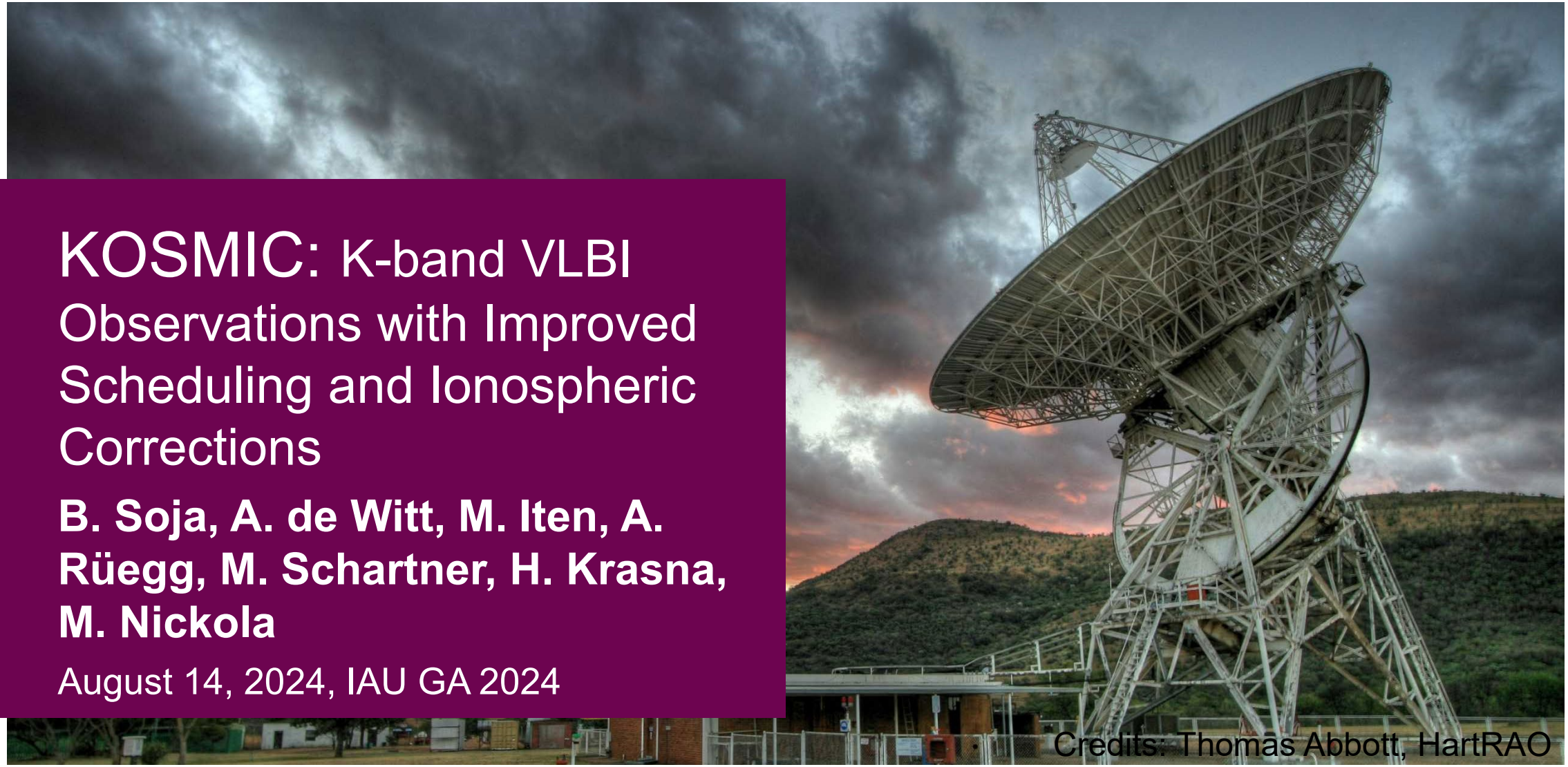
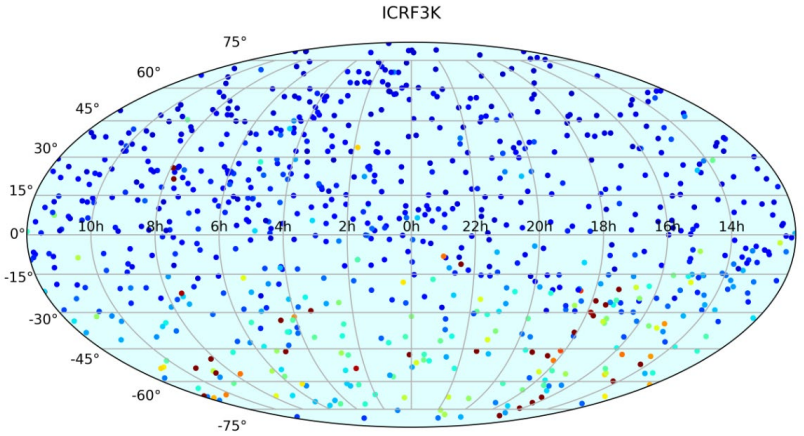
August 14, 2024, IAU GA 2024



Credits: Thomas Abbott, HartRAO

Background

- VLBI responsible for providing the International Celestial Reference Frame (ICRF)
- ICRF3 included CRF solutions at different frequencies, including K-band (24 GHz)
- K-band VLBI observations of high precision, but suffer from dispersive effects
- Ongoing initiatives to benefit from and further improve K-band VLBI



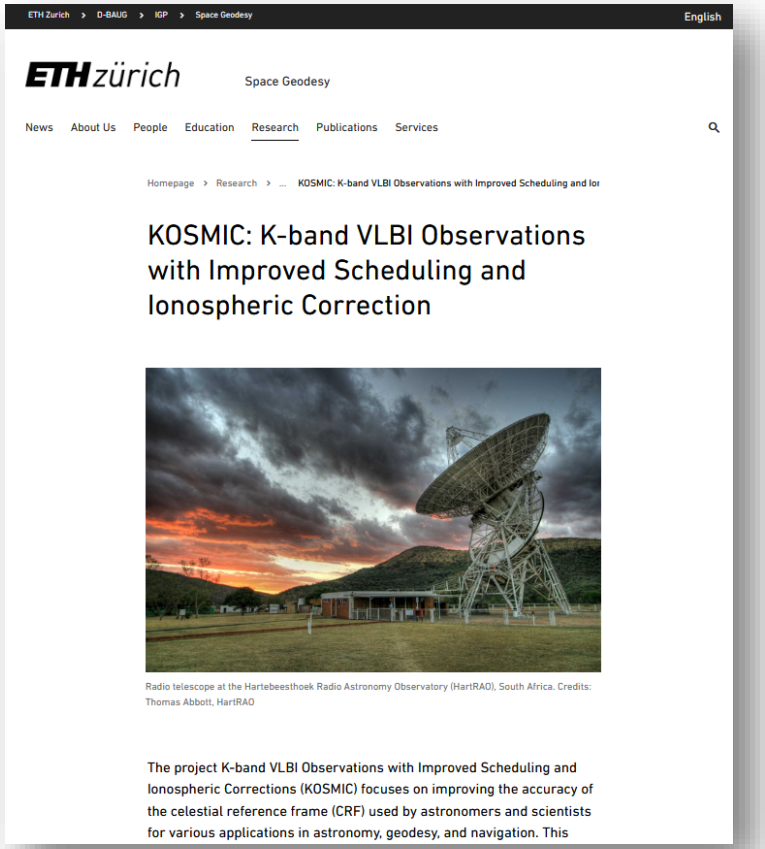
Charlot+2020

Introducing a new project: KOSMIC

KOSMIC: K-band VLBI Observations with Improved Scheduling and Ionospheric Correction

- Consortium ETH Zurich, HartRAO and TU Wien
- Funded by Swiss Tropical and Public Health Institute
- Website: https://space.igp.ethz.ch/research/kosmic.html

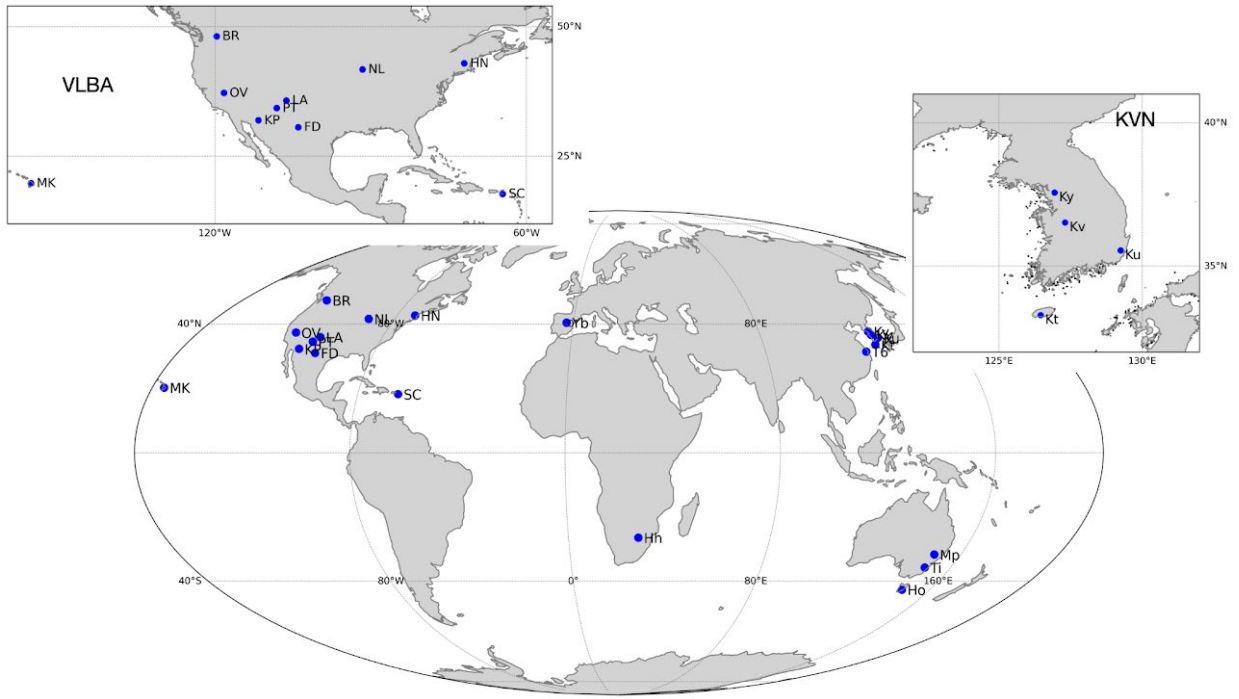
Main objectives
- Enhanced ionospheric corrections based on machine learning
- State-of-the-art scheduling of K-band observations



State-of-the-art scheduling of K-band observations

Challenges in scheduling K-band observations

- Currently scheduled with SCHED at short notice
  - Not clear in advance when VLBA is available
  - Requires a lot of manual work, especially how to cycle through sources
- Non-uniform network geometry between northern (mainly VLBA) and southern hemispheres

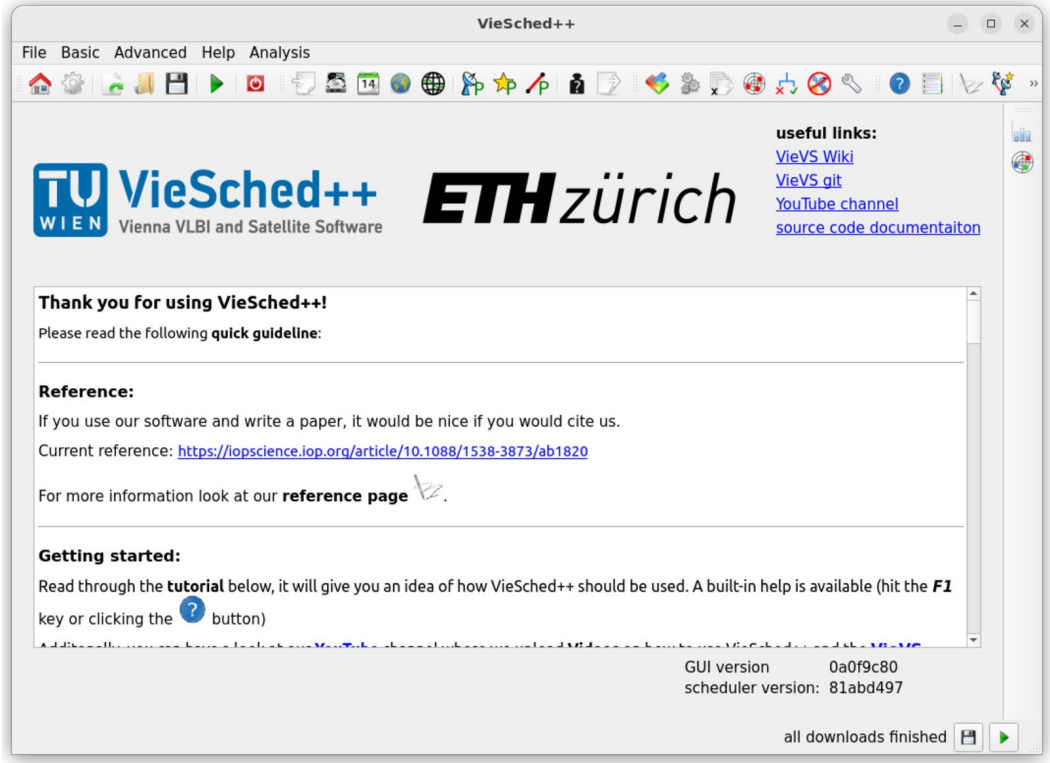


https://sites.google.com/sarao.ac.za/k-bandastrogeovlbi/network?authuser=0

Planned scheduling approach for K-band VLBI

- Automated scheduling with VieSched++
  - “Brute-force” Monte-Carlo approach to select optimal schedule
  - Increasingly used in IVS community

Key to successful K-band scheduling: understanding the objectives and translating them to optimization criteria



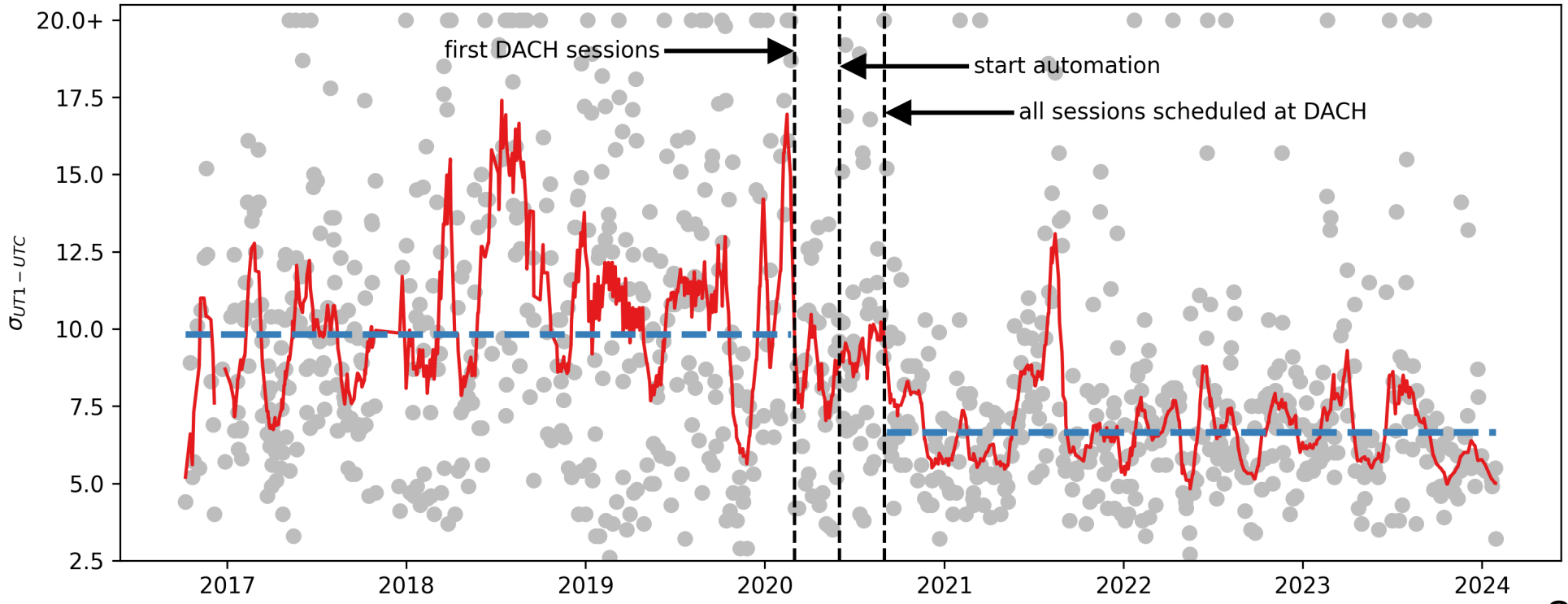
Schartner+2019

Benefits demonstrated in other observing programs

- Intensive INT2/3 sessions for dUT1

TU WIEN VieSched++ Vienna VLBI and Satellite Software

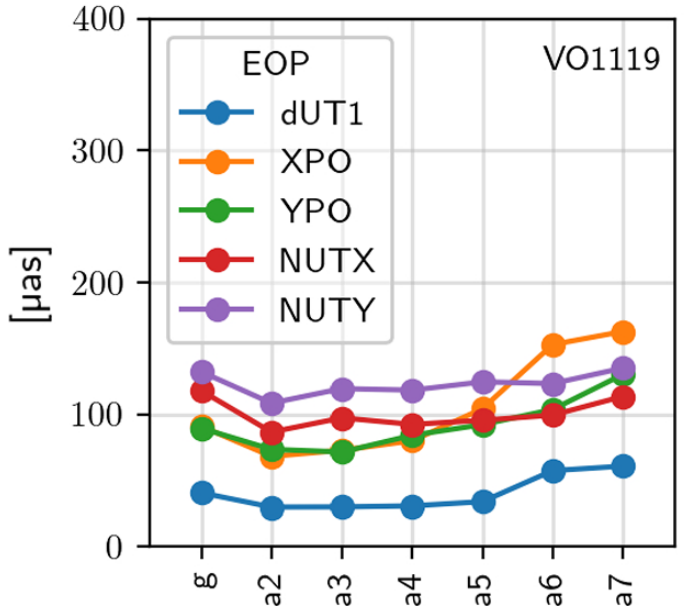
ETH zürich

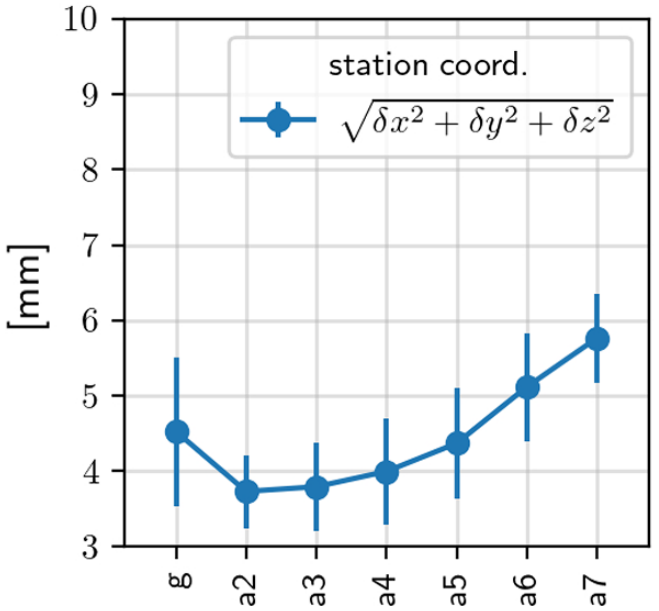


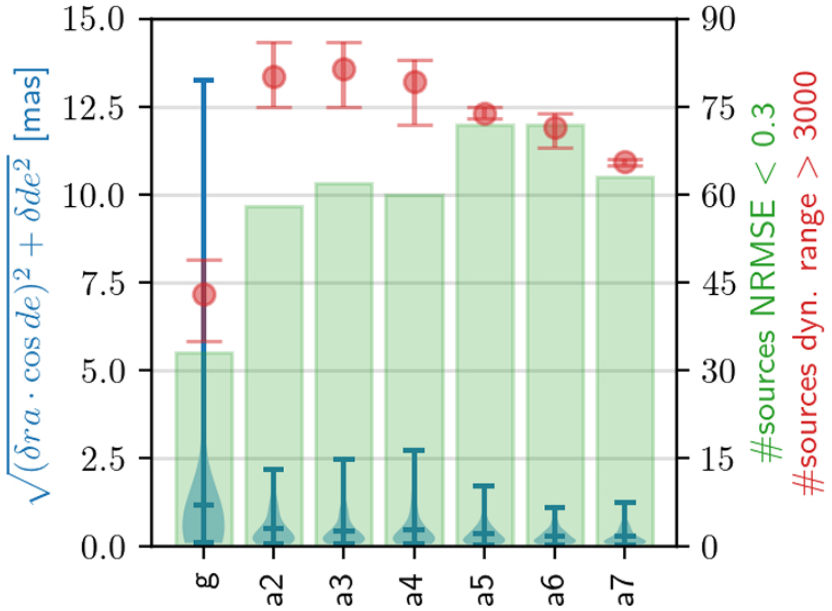
Schartner+2022

Bridging astronomical, astrometric and geodetic scheduling

- New source-centric scheduling approach
- Ideal for application in K-band VLBI







Schartner+2023

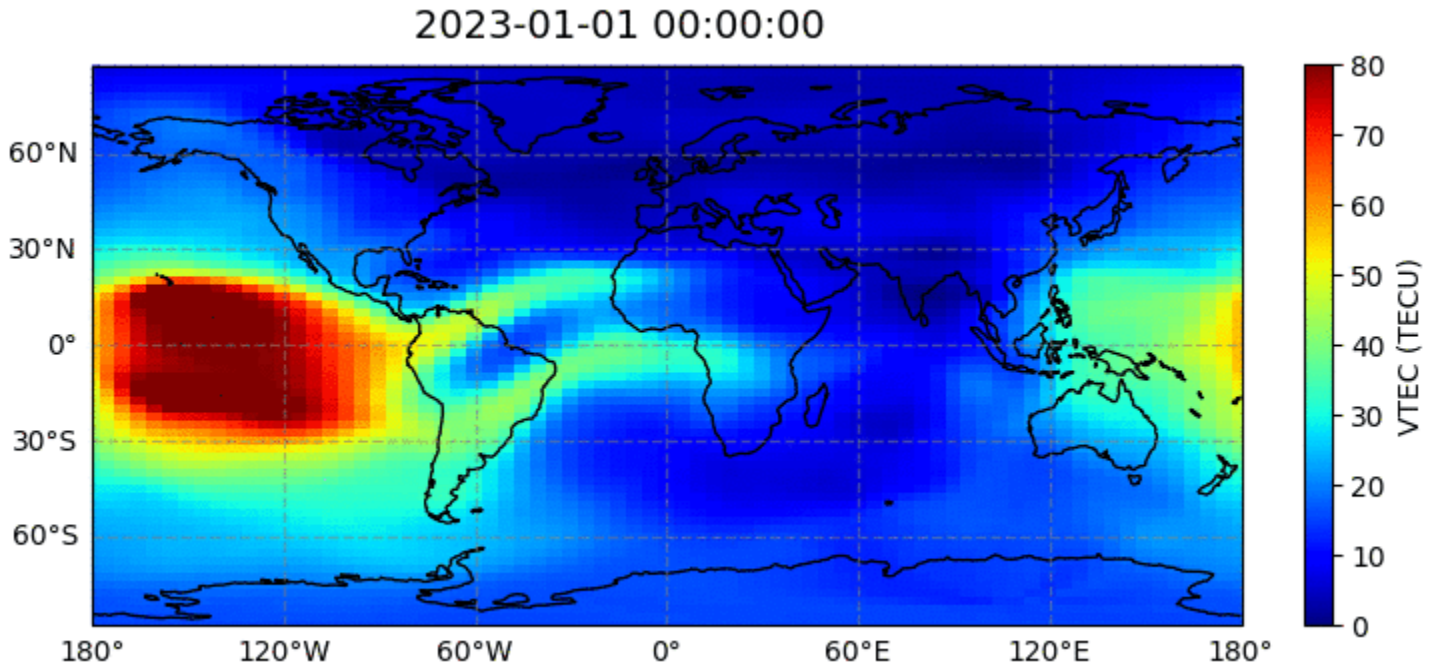
Enhanced ionospheric corrections based on ML

Global ionospheric modeling

- Ionospheric effects in K-band observations typically corrected with Global Ionospheric Maps (GIMs)
- GIMs model vertical total electron content (VTEC) in space and time
- Typically based on GNSS data and spherical harmonics

- Machine learning (ML)
  - Capable of capturing irregular and non-linear relationships
  - Benefits from large amounts of data

  → Ideal for ionospheric modeling

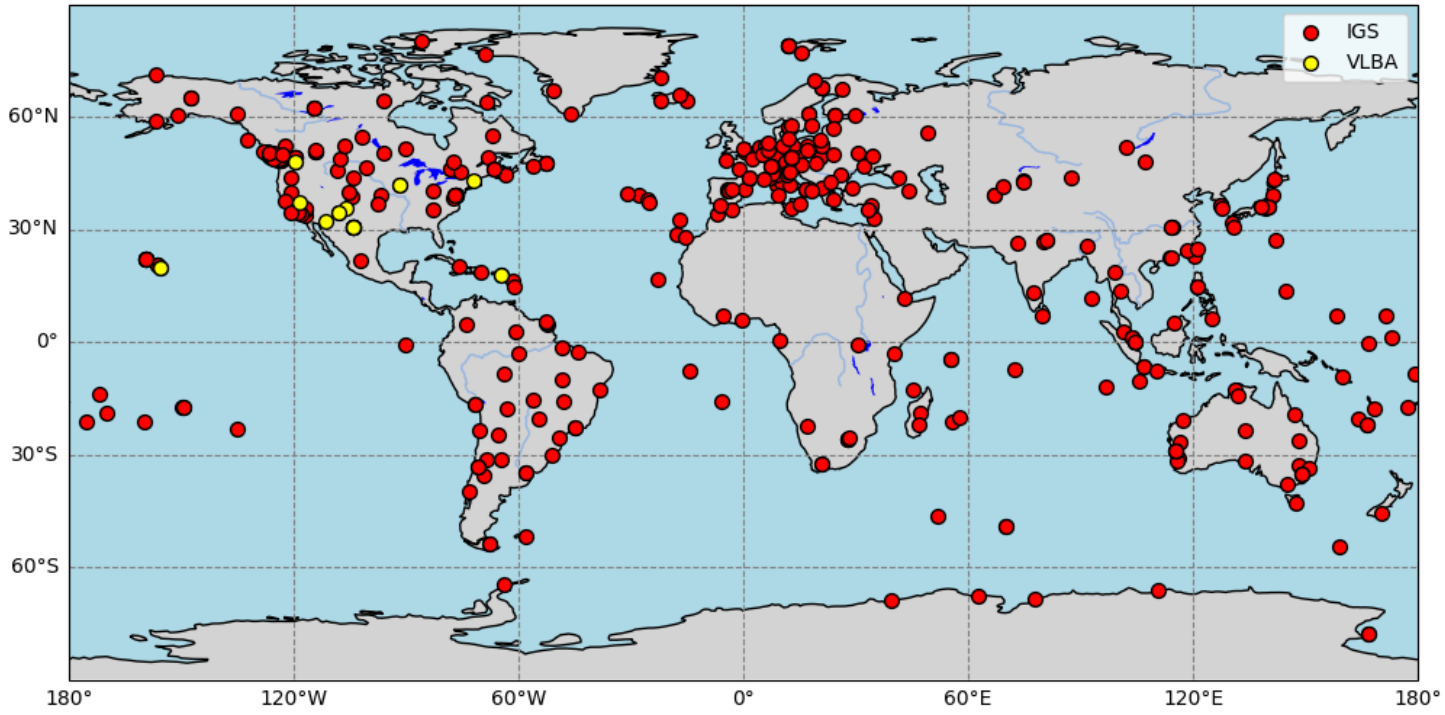


Mao+2024

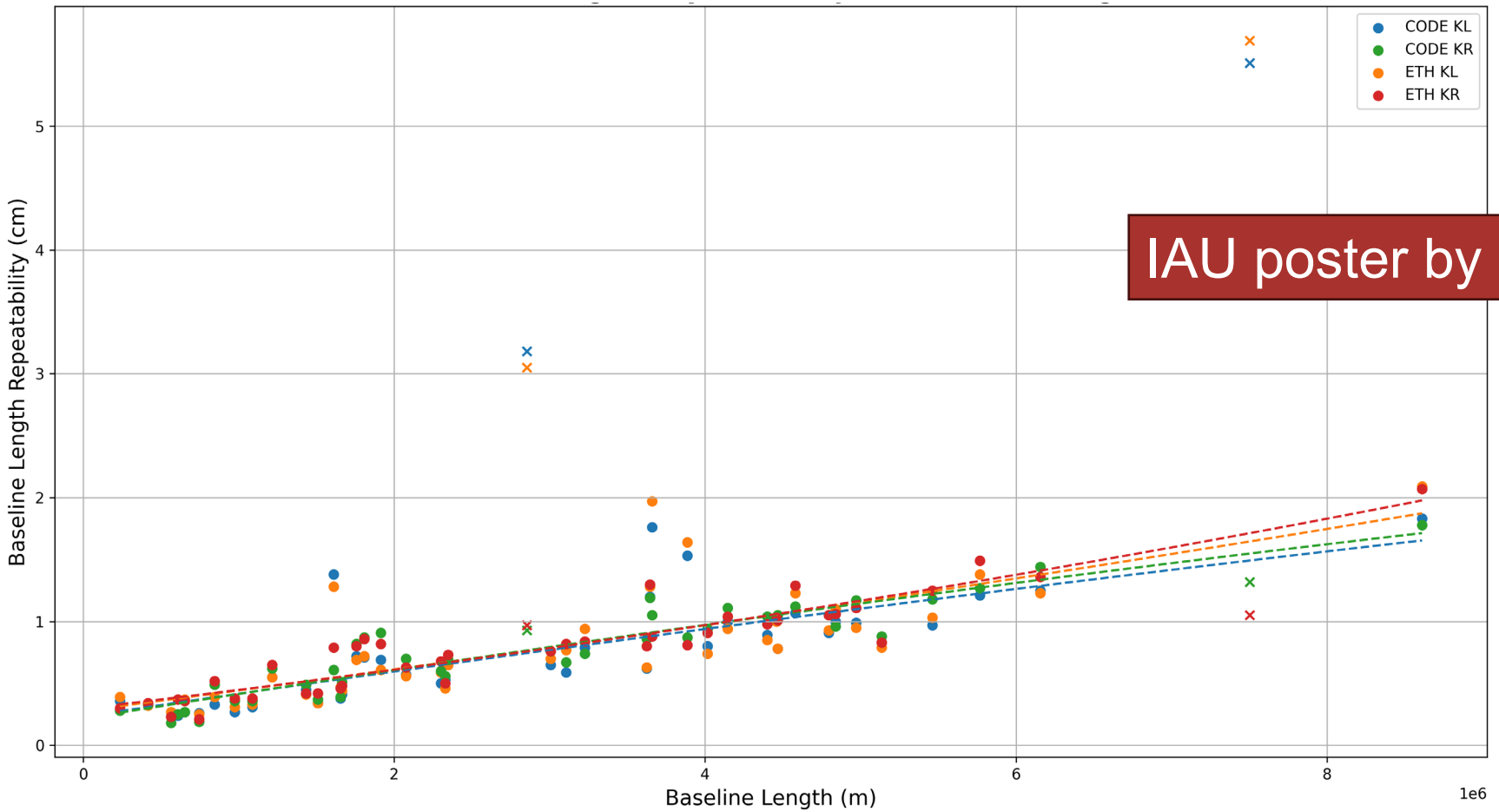
Methodology

- VTEC estimated from GNSS observations of IGS network
- Fully-connected neural network with 3 hidden layers & 60 neurons
  - Input: solar magnetic latitude & longitude, second of day & day of year (considering cyclic nature)
  - Target: VTEC
- VTEC extracted at K-band VLBI sites to correct ionospheric effects

Functional processing pipeline established



Preliminary results processing corrected K-band VLBI sessions

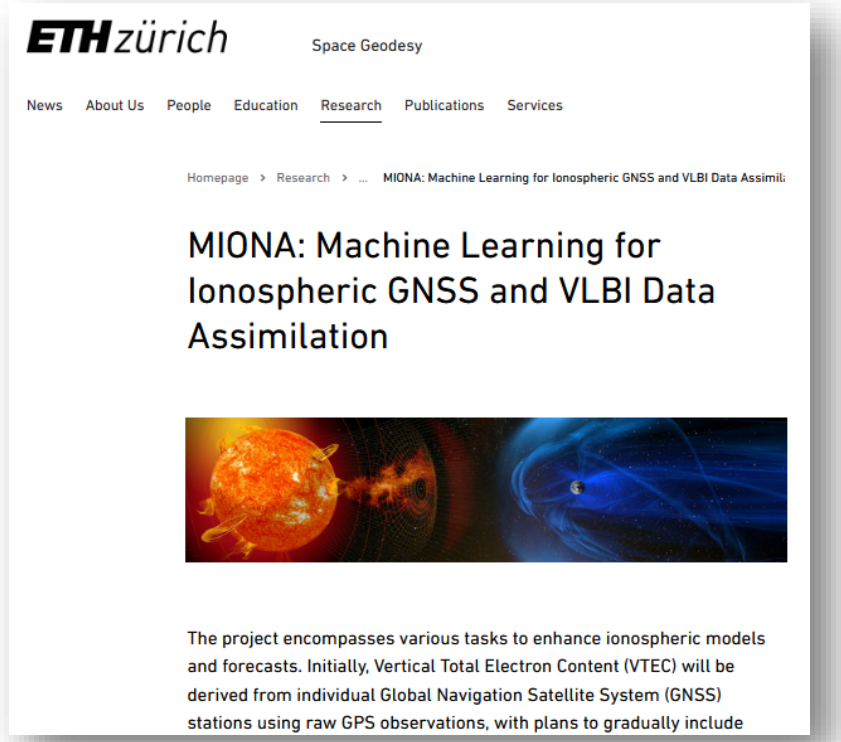


IAU poster by Iten+

Planned refinements of ML model

- Assimilate additional ionospheric data
  - More GNSS stations & improve initial processing
  - Altimetry, GNSS-RO
  - S/X-band VLBI and VGOS: IAU poster by Rüegg+
  - Solar and geomagnetic data

- Further improve ML approach
  - Positional encoding with spherical harmonics
  - Models over longer periods (currently 1 day)
  - Architecture and hyperparameter tuning
  - Specifically tune performance for K-band sites



Swiss National Science Foundation

Conclusions

- **KOSMIC** project to develop
  - Enhanced ionospheric corrections based on machine learning
  - State-of-the-art scheduling of K-band observations

- Promising **first results** using ionospheric corrections from **ML-based GIMs**

- Next steps:
  - **Refine ML models**
  - Source-centric **scheduling with VieSched++**

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Thanks for your attention!

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https://space.igp.ethz.ch

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Preliminary results processing corrected K-band VLBI sessions