SKA SWG Update

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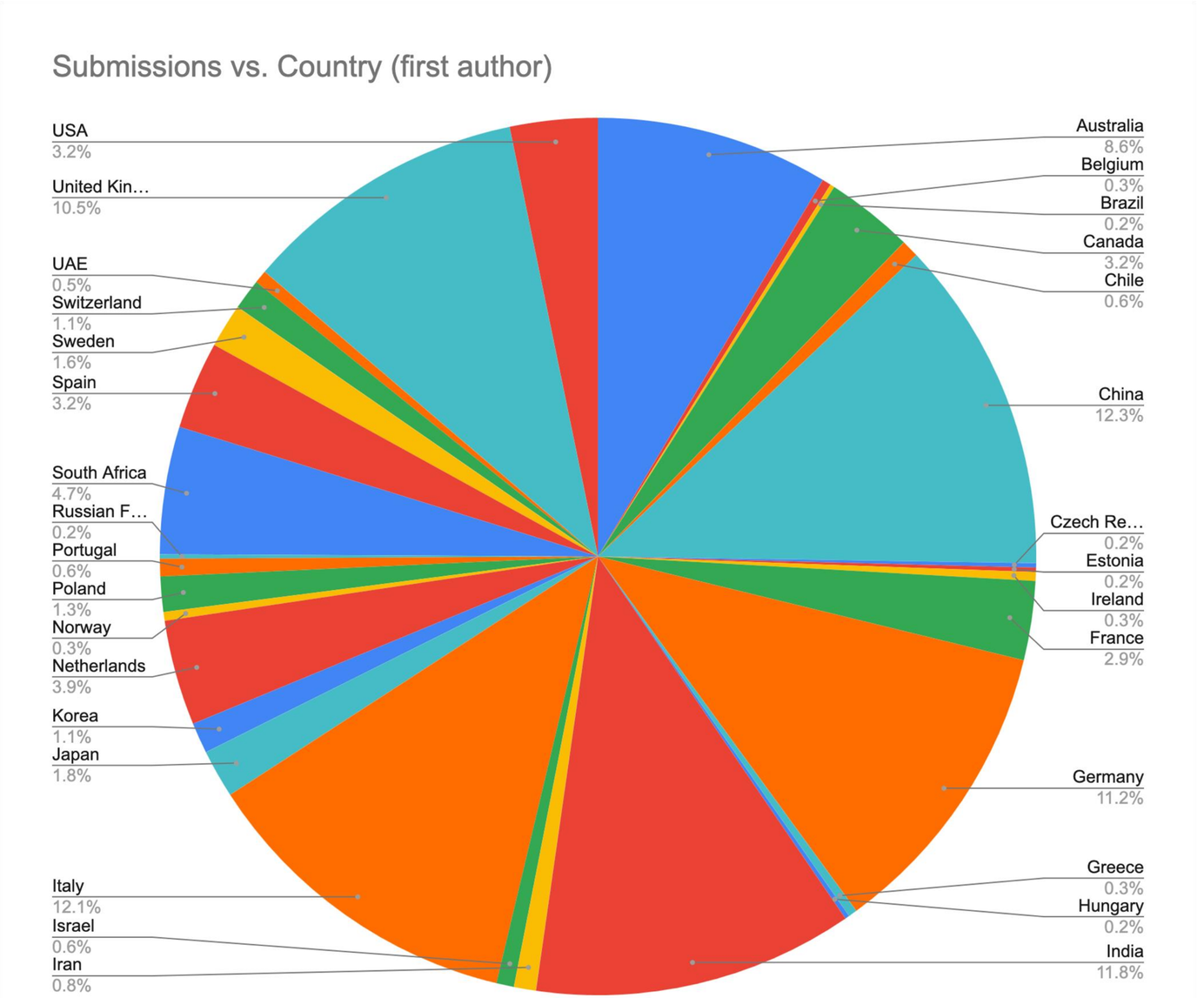
18/2/25

SKA Science Update

- SKA Science Meetings
- Science Data Challenges
- AOB

2025 Science Meeting: abstract submissions

- *Submissions now closed*
- Total submissions: 619
- Speaker notification:
  - 14 March
- Programme published:
  - 21 March
- Reduced fees until:
  - 28 March



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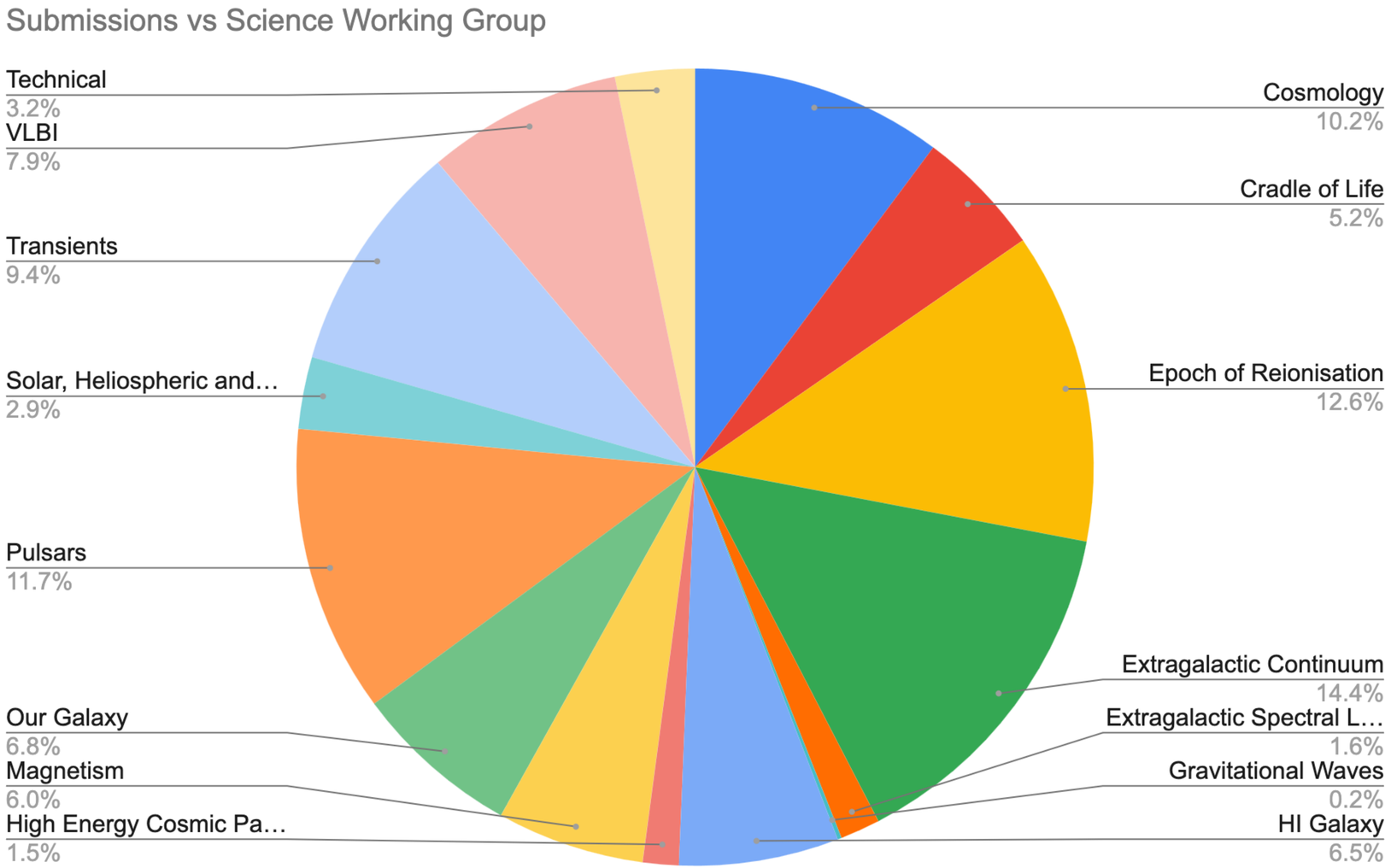


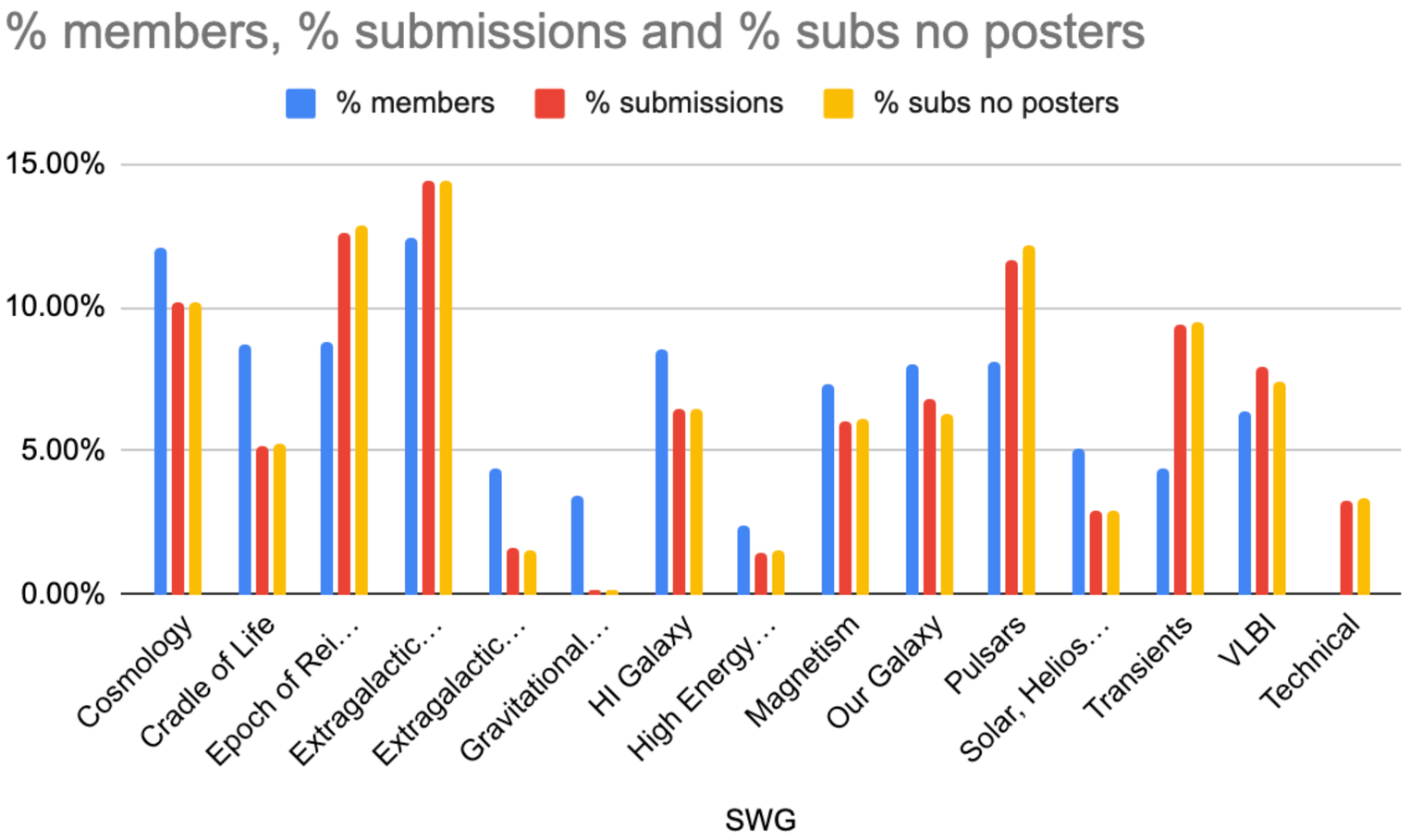
Programming

- **Plenary sessions**
  - Monday, Tuesday, Friday
  - Including “Observing with SKAO” special plenary session
- **Parallel sessions**
  - Wednesday morning and Thursday (1.5 days)
  - In order to facilitate SWG interaction and collaborations, organise into SWGs
    - Will also enable Operations to be able to offer tailored talks for different technical requirements
  - Participants will be asked at registration to indicate priority of (up to three) parallel sessions, in order to assign rooms (of differing sizes) to sessions
- **Posters**
  - ‘Lightning’ talks: aim to organise relatively early in the week in order to promote speakers’ posters for viewing

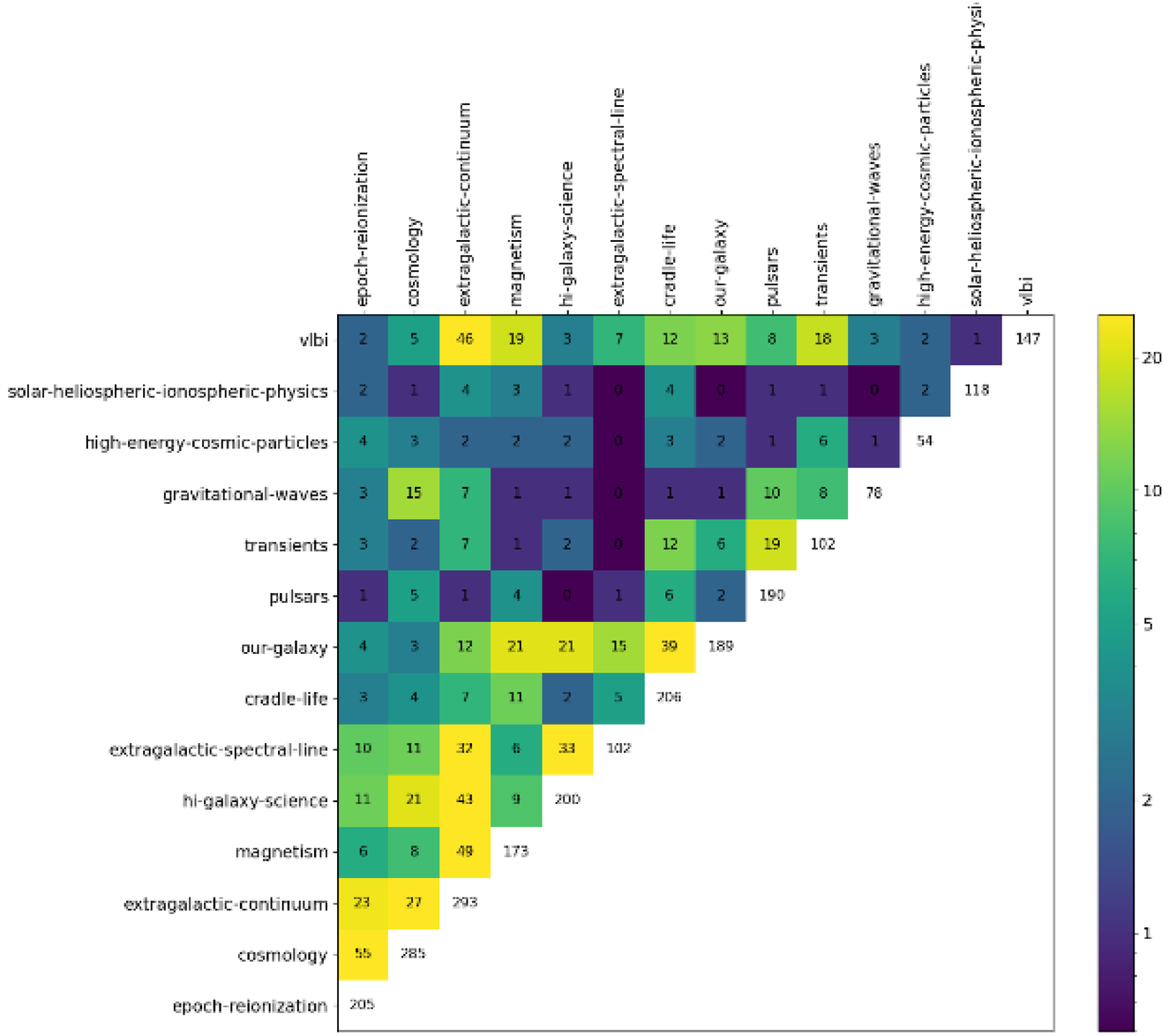
Parallel session planning

- 8 rooms available for parallel sessions
- 14 SWGs
- Proposed plan to organise the sessions:
  - First establish suitable pairings/groupings of SWGs per room (8 groupings)
    - Will use data from submissions, registrations, SWG membership to identify sizes and overlaps
  - Once groupings have been established and agreed, SOC representatives and SWG chairs of each grouping to decide how to split their parallel session time, with the following recommended guidelines for each grouping:
    - Around three quarters of a day per grouping for presentations
    - Around half a day for group-led discussion
    - Some time for Q&A session with Operations team
    - Can vary the above split of activities according to the requirements of each grouping

Parallel sessions: data from submissions



Parallel sessions: SWG member overlaps



Proposed SWG groupings:

- ExGalCont+Mag
- EoR
- Pulsars + GW
- Cosmology
- Transients + HECP
- VLBI+Technical
- HI+ExGalLine
- OG + CoL +SHI

“Observing with the SKAO” session

Draft titles of talks:

- Science operations
  - the operational model, including access, planning and Year in the Life etc
- What the AA* telescopes will be capable of
  - (setting the scene for the build out of modes and capabilities in the next talk)
- Timeline, rollout of modes and capabilities, building up over several cycles
- Science Verification planning
- Data products, pipelines
- SRCNet development
  - how the SRCNet will work for users
- User tools

Feedback on these topics welcome

Also looking to accommodate a panel discussion

SKAO confirmed sessions

- African Astronomical Society AfAS-2025 23-28 March 2025 University of South Africa (UNISA).
  - The SKA Observatory: status update and opportunities Tue 25/03 at 16.30-18.30 local time (14.30-16.30 UK).

- European astronomical society EAS-2025 23 – 27 June 2025 University College Cork, Ireland
  - Lunch session The SKA Observatory: preparing the community for SKA science

Science Data Challenge 3a: EoR Foregrounds

Square Kilometre Array Science Data Challenge 3a: foreground removal for an EoR experiment

TBC

7 February 2025

ABSTRACT

We present and analyse the results of the Science data challenge 3a (SDC3a, https://sdc3.skao.int/challenges/foregrounds), an EoR foreground-removal community-wide exercise organised by the Square Kilometre Array Observatory (SKAO). The challenge run for 8 months, from March to October 2023. Participants were provided with realistic simulations of SKA-Low data between 106 MHz and 196 MHz, including foreground contamination from extragalactic as well as Galactic emission, instrumental and systematic effects. They were asked to deliver cylindrical power spectra of the EoR signal, cleaned from all corruptions, and the corresponding confidence levels. Here we describe the approaches taken by the 17 teams that completed the challenge, and we assess their performance using different metrics.

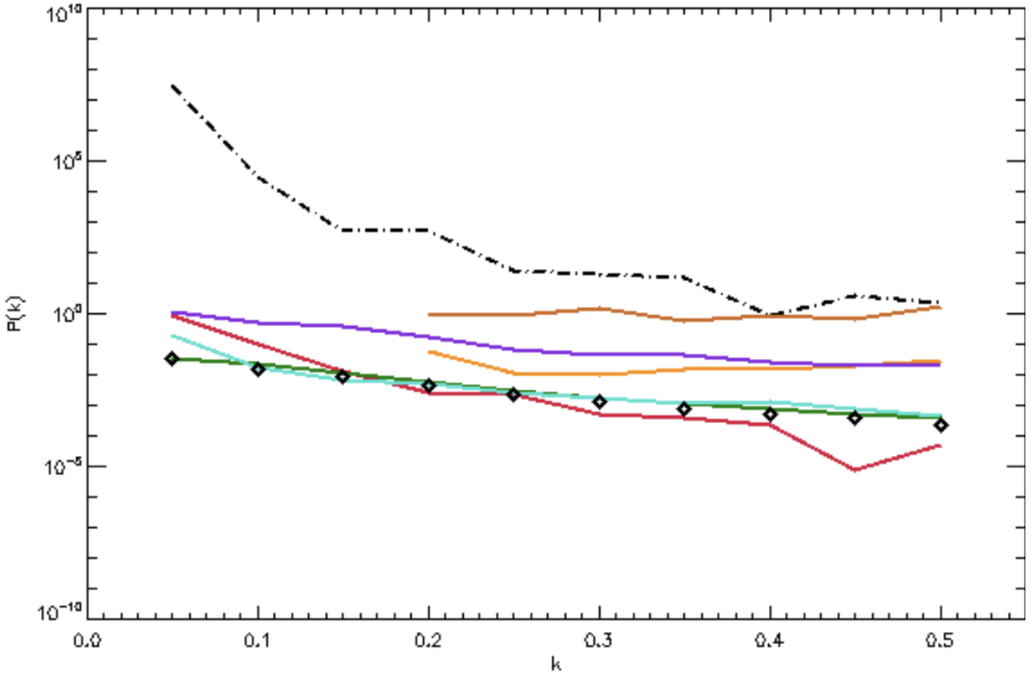
The challenge results provide a positive outlook on the capabilities of current foreground-mitigation approaches to recover the faint EoR signal from SKA-Low observations. The median error committed in the EoR power spectrum recovery is below the true signal for seven teams, although in some cases there are some significant outliers. The smallest residual overall is $4.2^{+20}_{-4.2} \times 10^{-4}$ $K^2h^{-3}cMpc^3$ across all considered scales and frequencies.

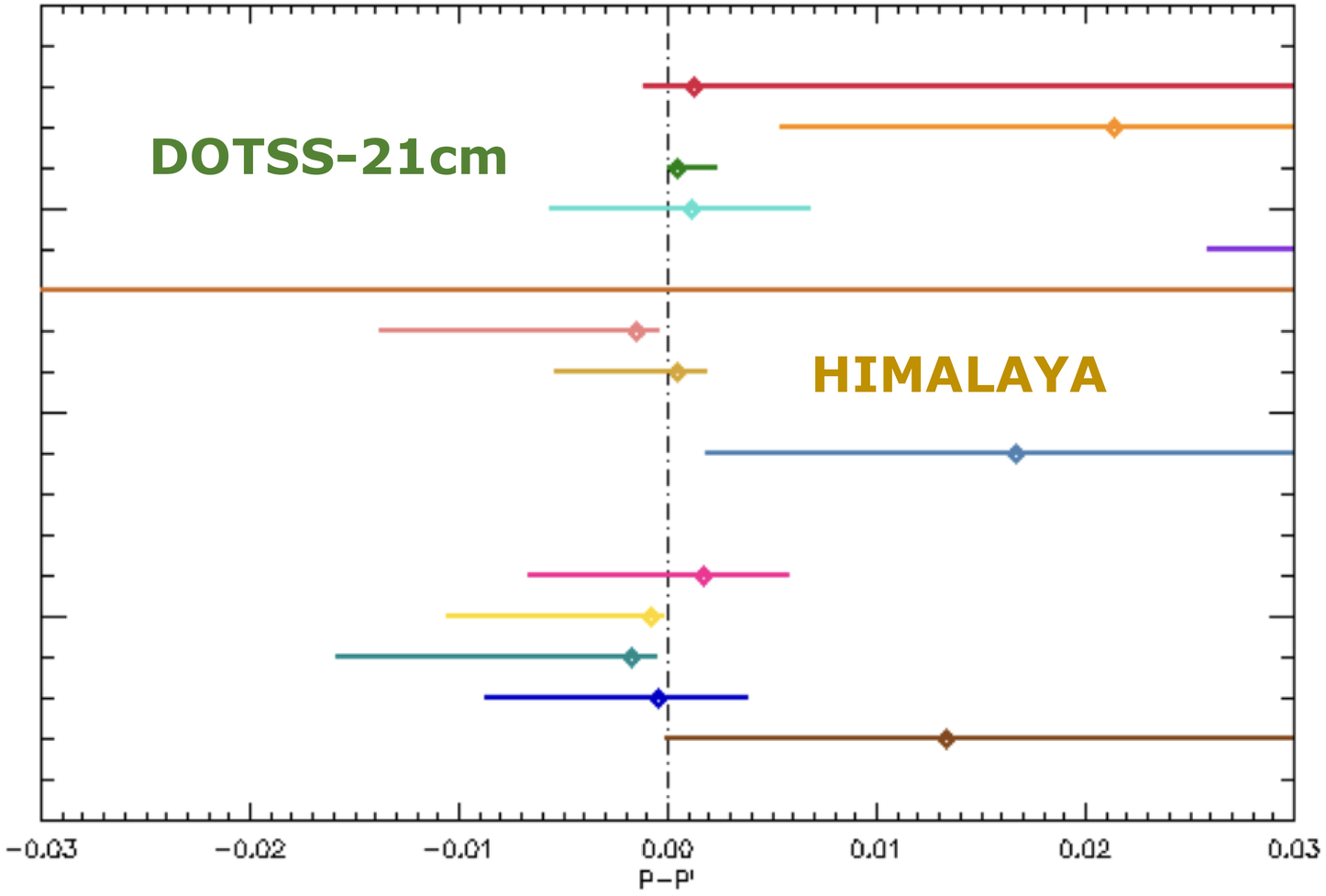
The estimation of confidence levels provided by the teams is overall less accurate, with the true error being typically underestimated, sometimes very significantly. The most accurate error bars account for 60 ± 20% of the true errors committed. The challenge results provide a means for all teams to understand and improve their performance. This challenge indicates that the comparison between independent pipelines could be a powerful tool to assess residual biases and improve error estimation.

Paper undergoing internal review

Author list being collated: challenge team members, HPC facility partners, SDC organisers

Science Data Challenge 3a: EoR Foregrounds





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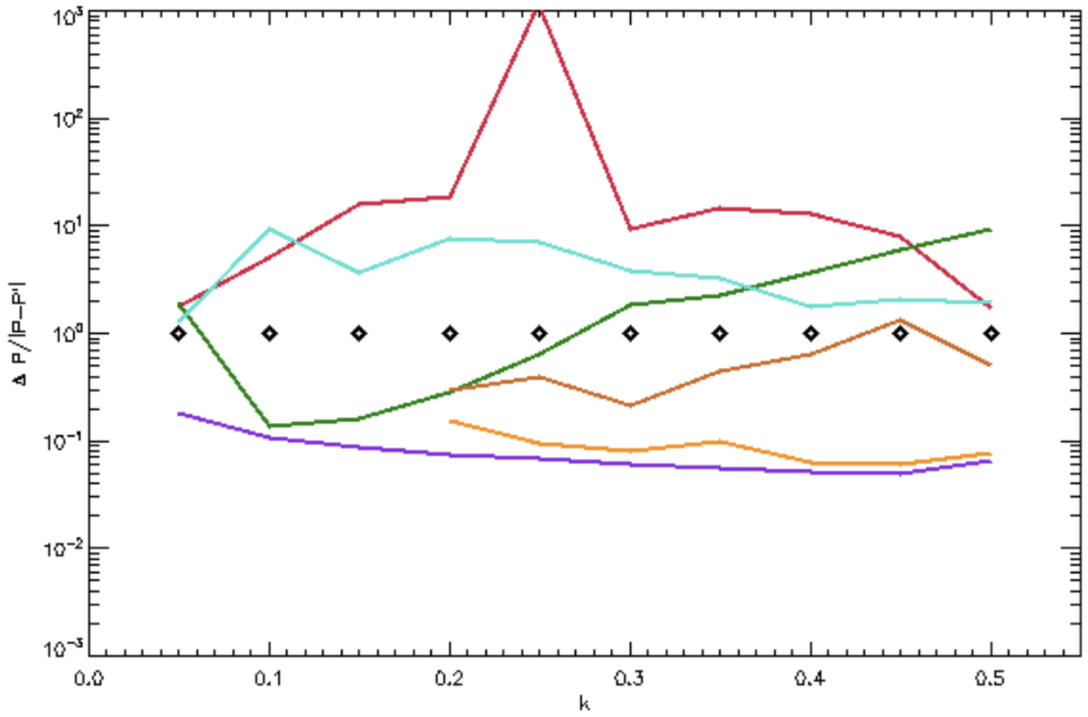
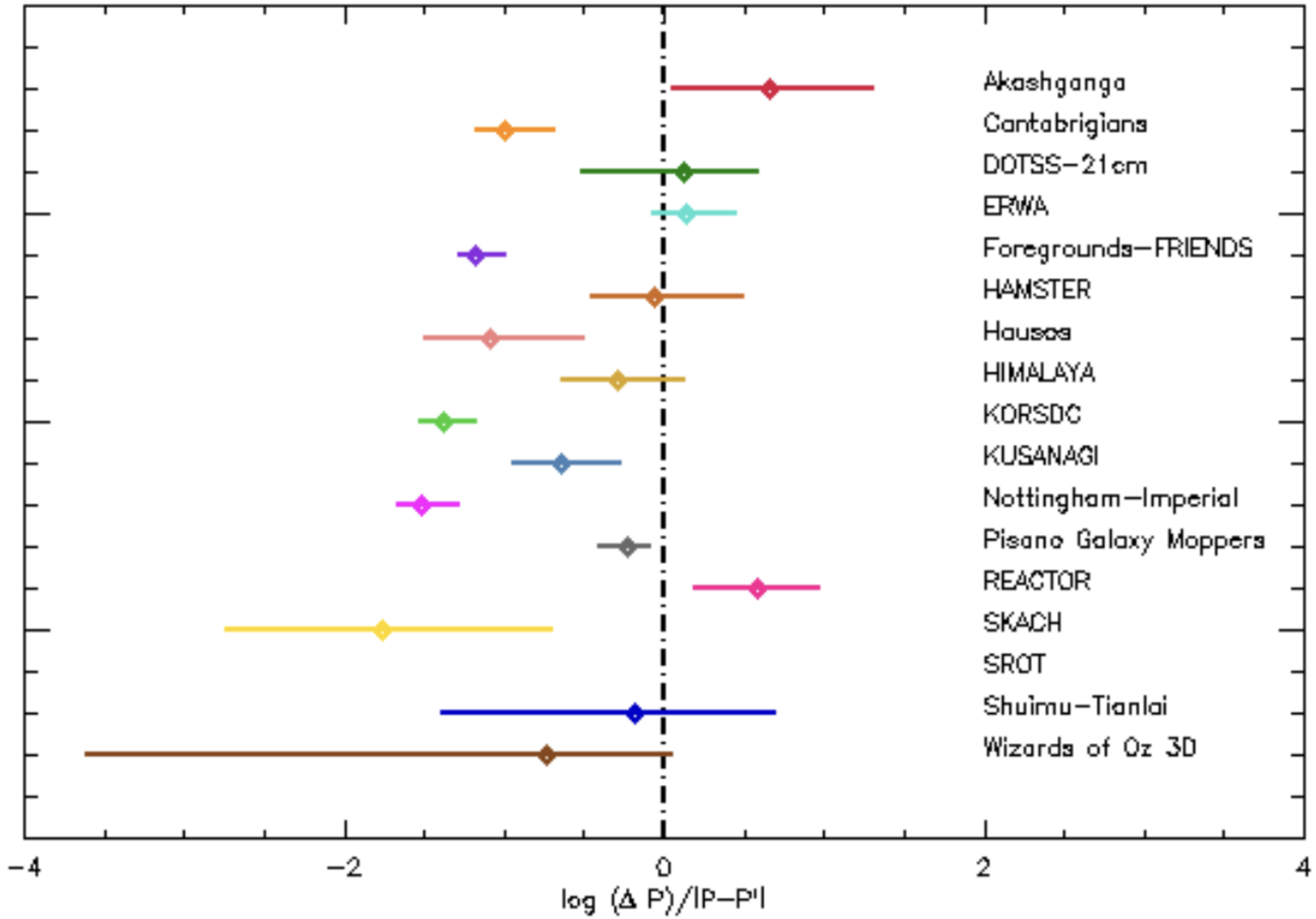




Science Data Challenge 3a: EoR Foregrounds

SKA-Low simulations for a cosmic dawn/epoch of reionisation deep field

TBC

7 February 2025

ABSTRACT

We present a realistic simulation of an SKA-Low cosmic dawn/epoch of reionisation (CD/EoR) observation, which can be used to further the development of foreground-mitigation approaches. The simulation corresponds to a deep (1000 h) integration pointing over the 106 MHz–196 MHz frequency range. The sky components include the CD/EoR signal, extragalactic foreground emission featuring strong out-of-field sources and in-field sources down to 1 μJy at 150 MHz, and Galactic emission from the GSM2016 model complemented with small-scales structure beyond the native $\sim$ 1 deg resolution of that model from a magneto-hydro-dynamic simulation of the interstellar medium. Modeled errors include a partial de-mixing of the out-of-field sources, direction-dependent calibration errors leading to residual ionospheric effects, and direction-independent gain calibration errors, on top of thermal noise. Simulated observations are delivered as visibilities as well as imaging products both with natural and uniform weighting. The true, uncorrupted, CD/EoR signal is also delivered, to allow an assessment of the efficacy of foreground-mitigation approaches. The codes used to generate these simulations are also delivered, so that new simulated datasets can be produced. This simulation has been the basis for the SKA Science Data Challenge 3a (SDC3a), which addressed foreground removal.

Key words:

Companion paper on the simulation in preparation

All codes to be released as well!

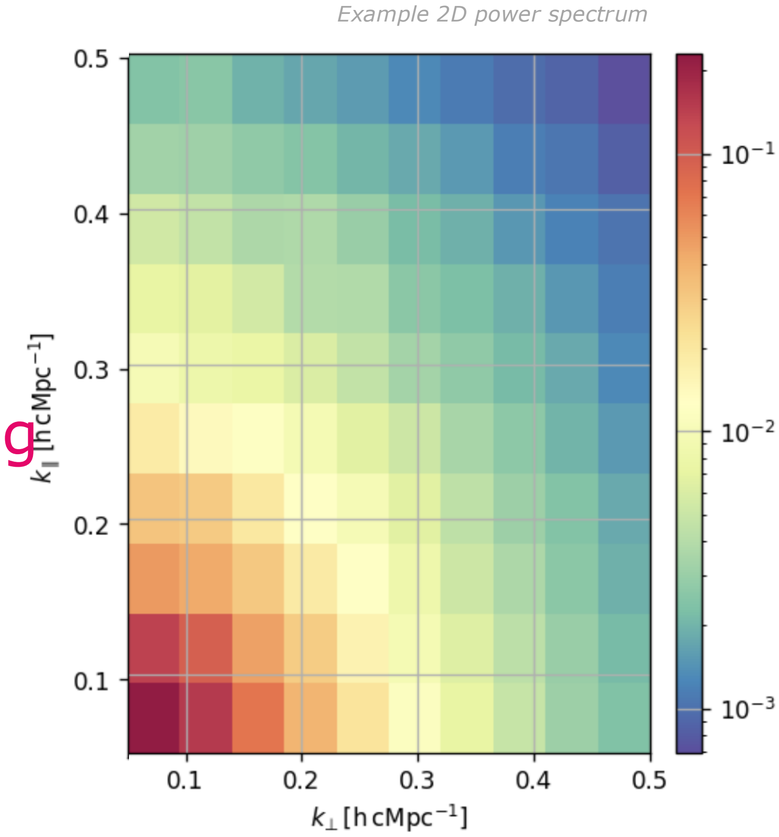
Science Data Challenge 3b: EoR Inference

- The datasets:
  - PS1: Power spectra of EoR1 + noise + SKA-Low telescope simulation for one simulation code
  - PS2: Power spectra of EoR1 + noise + SKA-Low telescope simulation for another simulation code
  - PS3: Power spectra of EoR1 + noise + foreground residual + SKA-Low telescope simulation
  - IM1: imaging product corresponding to PS3 (includes foreground residual)

- Status: ongoing. Deadline for results: 30th April 2025

released

upcoming



Science Data Challenge 3b: EoR Inference

- The challenge:
  - Infer the reionization properties of the Universe from power spectra of the hydrogen-21cm signal from the Epoch of Reionisation corresponding to different redshift ranges.
  - Submission will consist of inferred reionization fraction of the Universe for all the redshifts for which power spectra have been provided, and the associated uncertainty.
- Computational support
  - SDC3 receives generous support from our international HPC partner facilities, who will provide computational resources to teams for processing the challenge data.

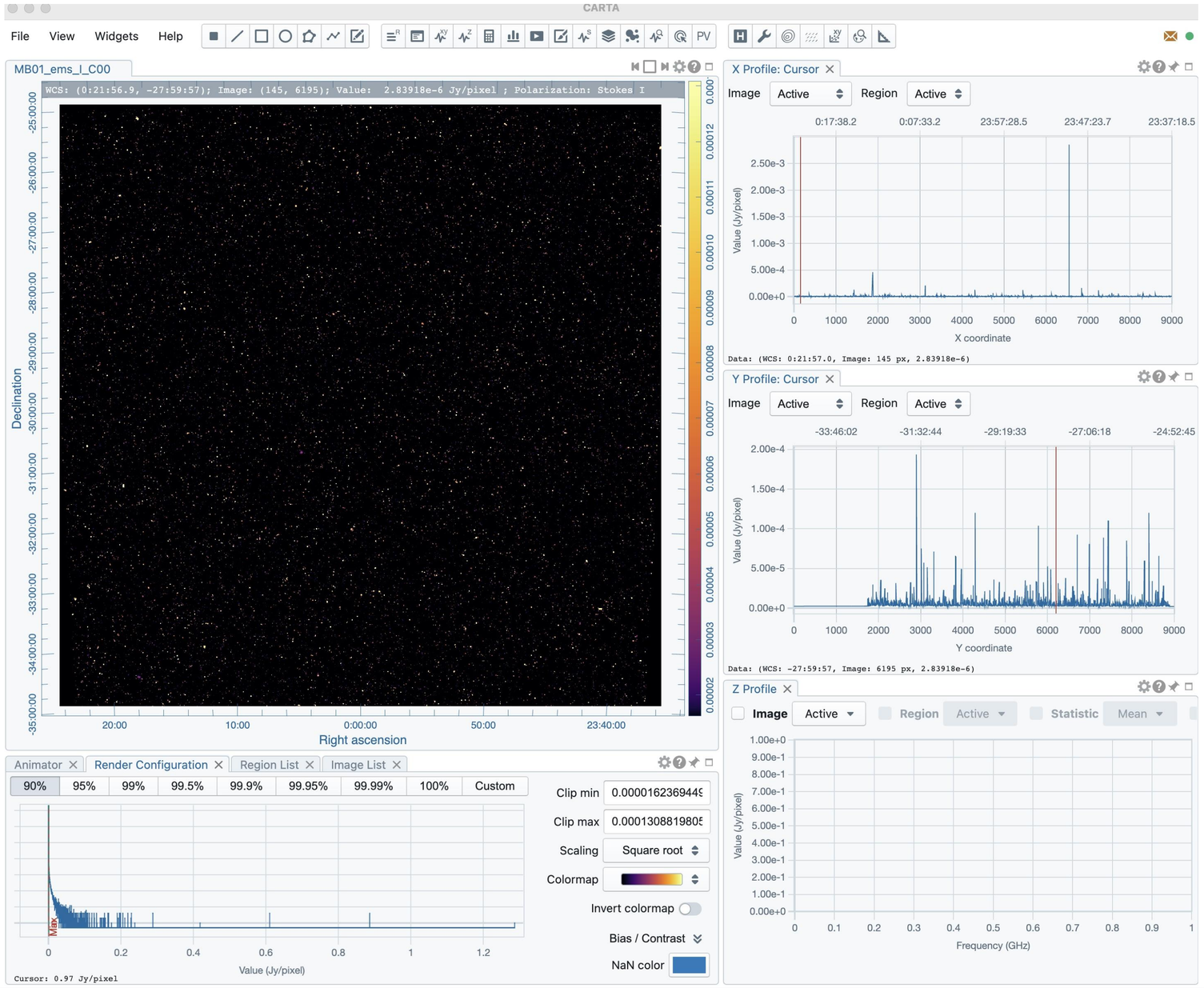
Science Data Challenge 4 – Magnetism

- Developed in collaboration with Magnetism SWG (Akahori, Vernstrom, Vazza, …)
  - Stokes IQU compact plus diffuse sky model with IGM, ISM, and ionosphere propagation
  - 9 square deg, 950 – 1760 MHz, 3 arcsec beam, RM_{Max} ~ 5000 rad m^{-2}, N_{chan} ~ 650, data products of (9000x9000 pixels)
  - 100 square deg, 150 – 350 MHz, 350 – 1760 MHz, 10 arcsec beam, RM_{Max} ~ 500 rad m^{-2}, N_{chan} ~ (6000 + 650), data products of (9000x9000 pixels)
  - Thermal noise equivalent ~5000 h for each Band with AA* telescope model

Science Data Challenge 4 – Magnetism

- Sky Emission Model consists of:
  - T-RECS point source population (all z)
  - IGM emission (z < 0.3)
  - ISM emission
- Propagation Model consists of:
  - IGM RM (z < 3.15)
  - ISM RM
  - Ionosphere RM

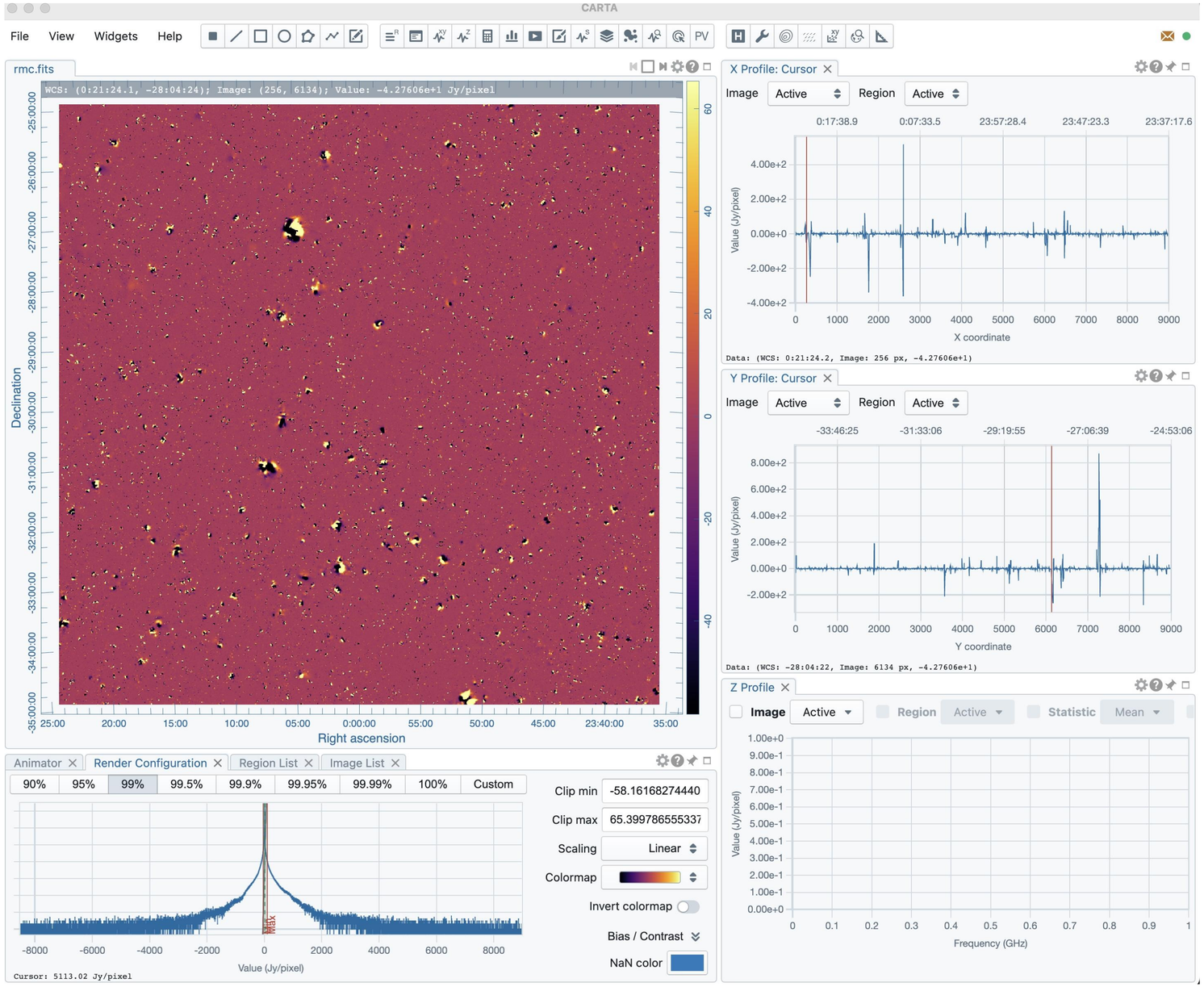
Stokes I Sky Model



Science Data Challenge 4 – Magnetism

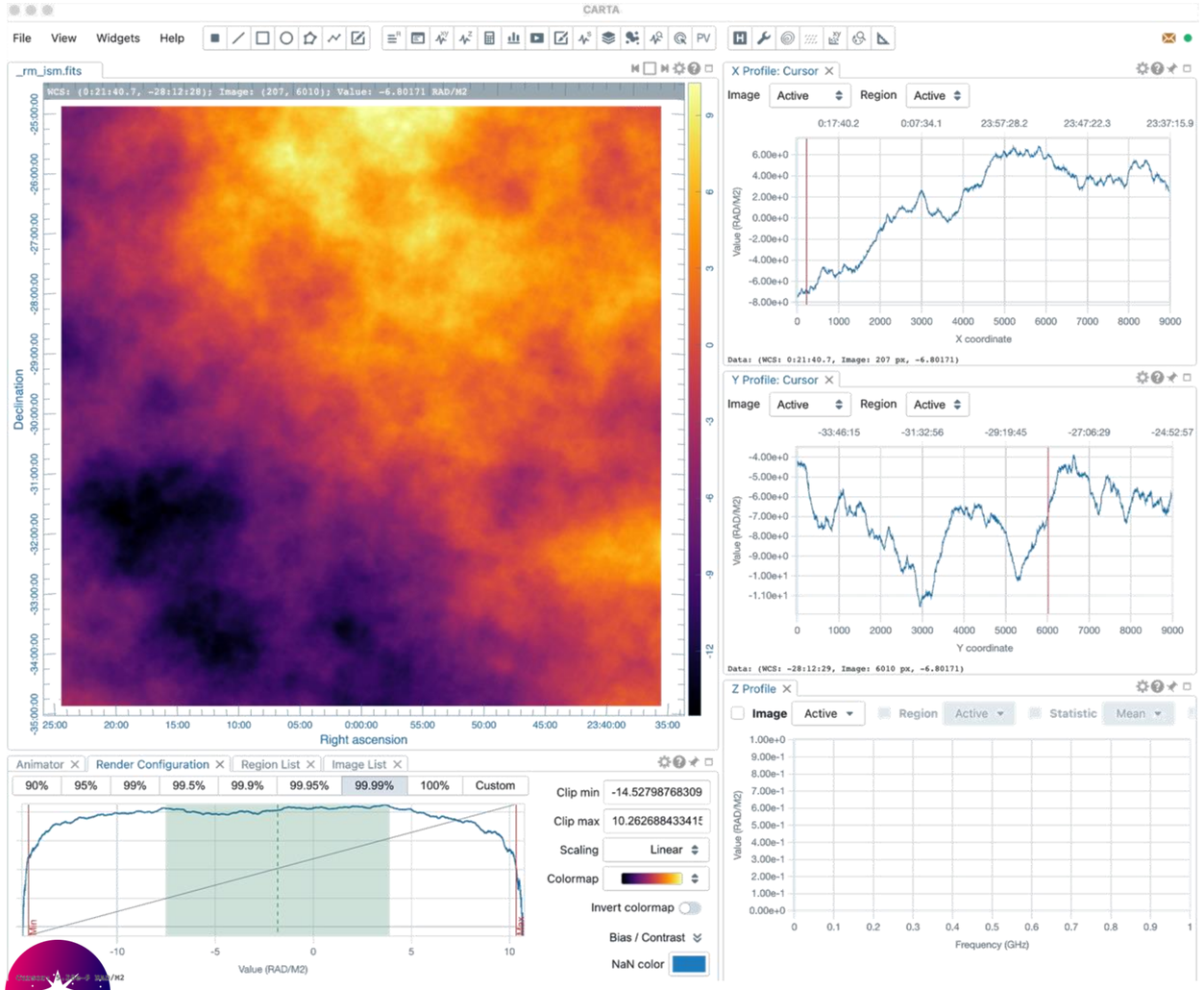
- IGM RM Sky Model of 100 deg^2 extending from z = 0.01 to 3.2 using Vazza et al simulations
- Red-shift space built up of 70 slices of 100 Mpc depth
- Each slice is the simulation at that red-shift tiled as needed to fill 10x10 deg, with an offset and rotation to randomize projected distribution

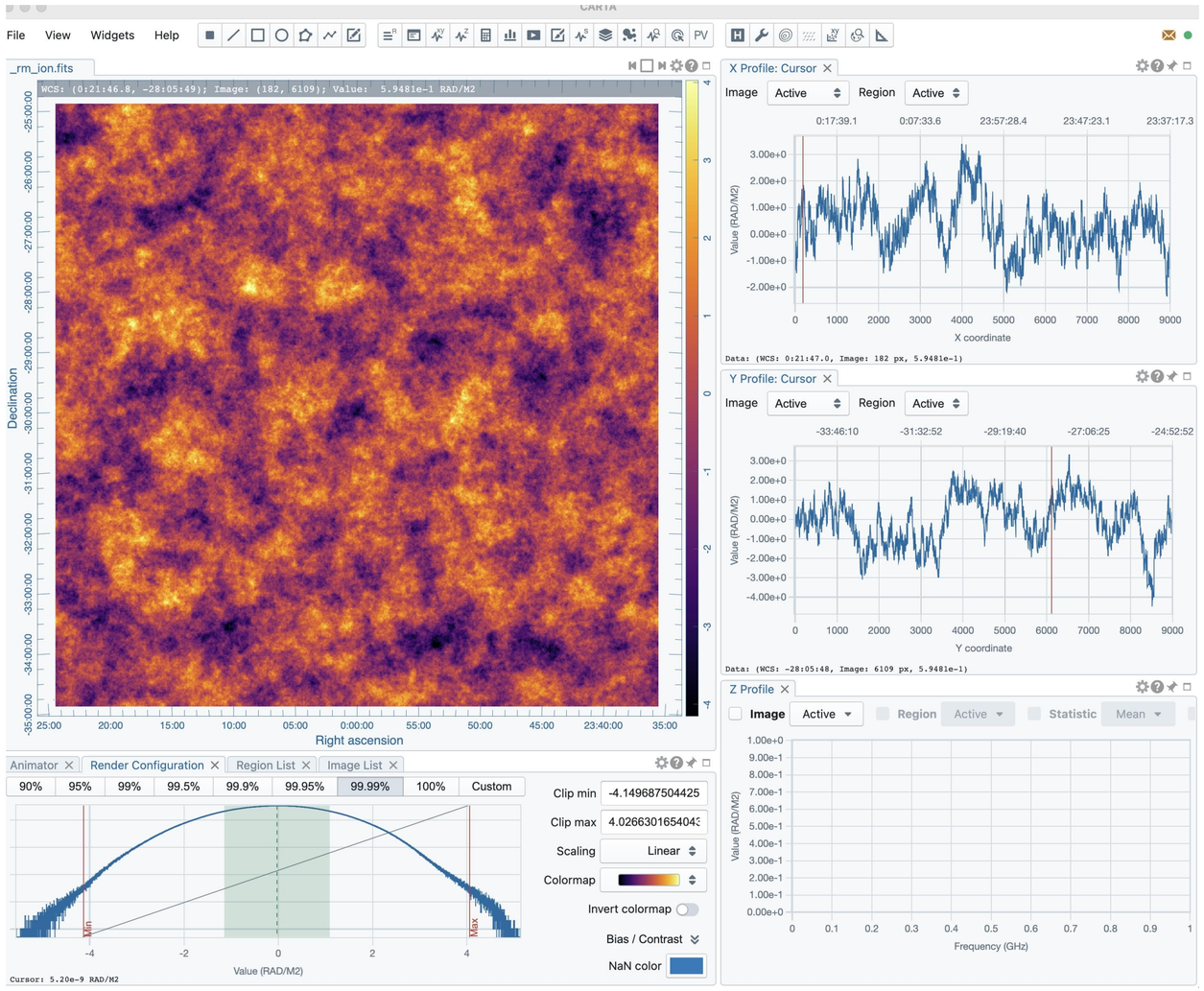
Projected RM(z) Sky Model (z = 0.01 – 3.2)



Science Data Challenge 4 – Magnetism

- ISM and Ionosphere RM Sky Model of 100 deg^2 from Akahori et al simulations
- Also include ISM polarised emission from Akahori et al model





Science Data Challenge 4 – Magnetism

- Telescope, RFI and Error Models
  - Image-based rather than visibility-based due to prohibitive computing cost
  - Hexagonal mosaic sampling pattern that extends (with pointing centres) 10% beyond nominal survey region leaving realistic edge effects: ~10% in sensitivity
  - Instrumental QUV off-axis polarisation due to elliptical X and Y voltage beams: ~ $10^{-3/-4}$
  - RFI model uses on-site TP data as basis for elevated Tsys and short baseline flagging that modifies dirty PSF at each frequency (only one PSF, rather then per mosaic pointing)

SDC4 Magnetism: Data Products, Goals, Timeline

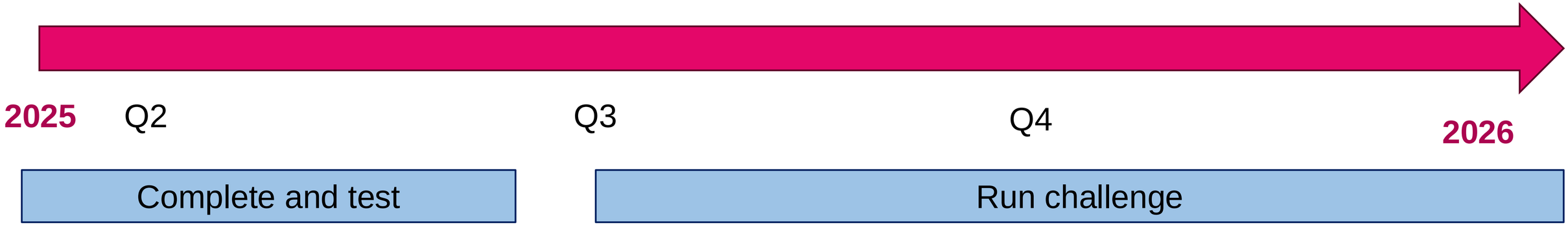
- IQUV images at sequence of centre frequencies ($\Delta\nu \sim \nu^3$) matched to RM_{Max} = 500 or 5000 with depolarisation (due to $\Delta\nu$) of < 5%
- Ancillary Products:
  - Dirty PSF, Mosaiced I and I^2, Mosaiced instrumental QUV
  - (Propagated complete IQU sky model, and RM(z) not public during challenge)
- Total size:
  - **9 deg²**: 650x10x324 MB = 2.1 TB, **100 deg²**: 6650x10x324 MB = 21.5 TB

Open questions

- Missing data products ?
- Additional challenge goals (beyond recovery of intrinsic IQU plus RM source catalogue)
  - IQU from diffuse IGM is extremely faint (10s of nJy/beam) so not really viable in this depth of obs
  - Some instances of magnetised Large-Scale Structure aligned with (extended) background sources
- HPC resourcing needed per team: storage, memory, CPU-h/GPU-h

➢ Consult with magnetism SWG members, enlist a few of them to inspect the data products.

SDC4: current status and tentative timeline



Any Other Business

- News from SWG Chairs?
- …

We recognise and acknowledge the Indigenous peoples and cultures that have traditionally lived on the lands on which our facilities are located.

SKAO

www.skao.int

www.skao.int/en/science-users