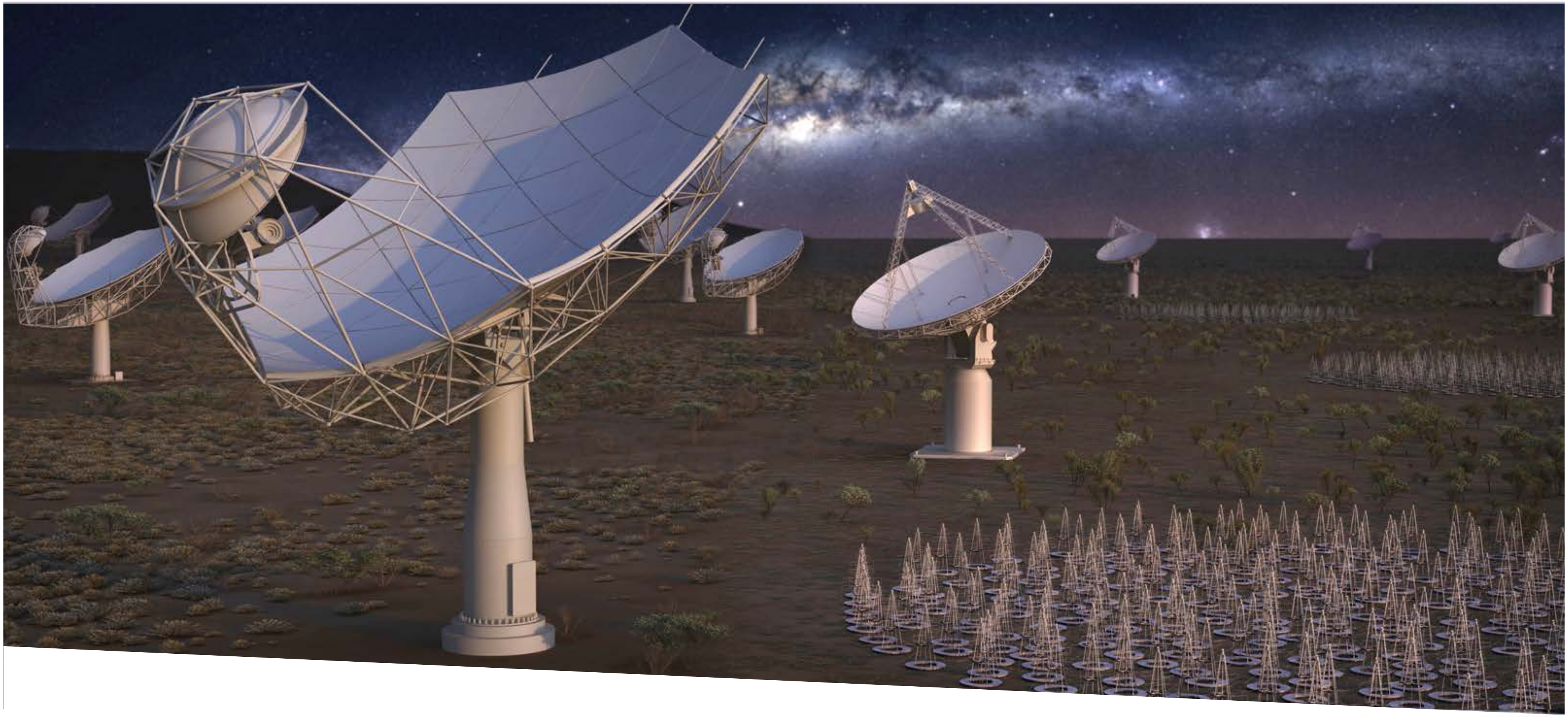
SKA SWG Update



SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

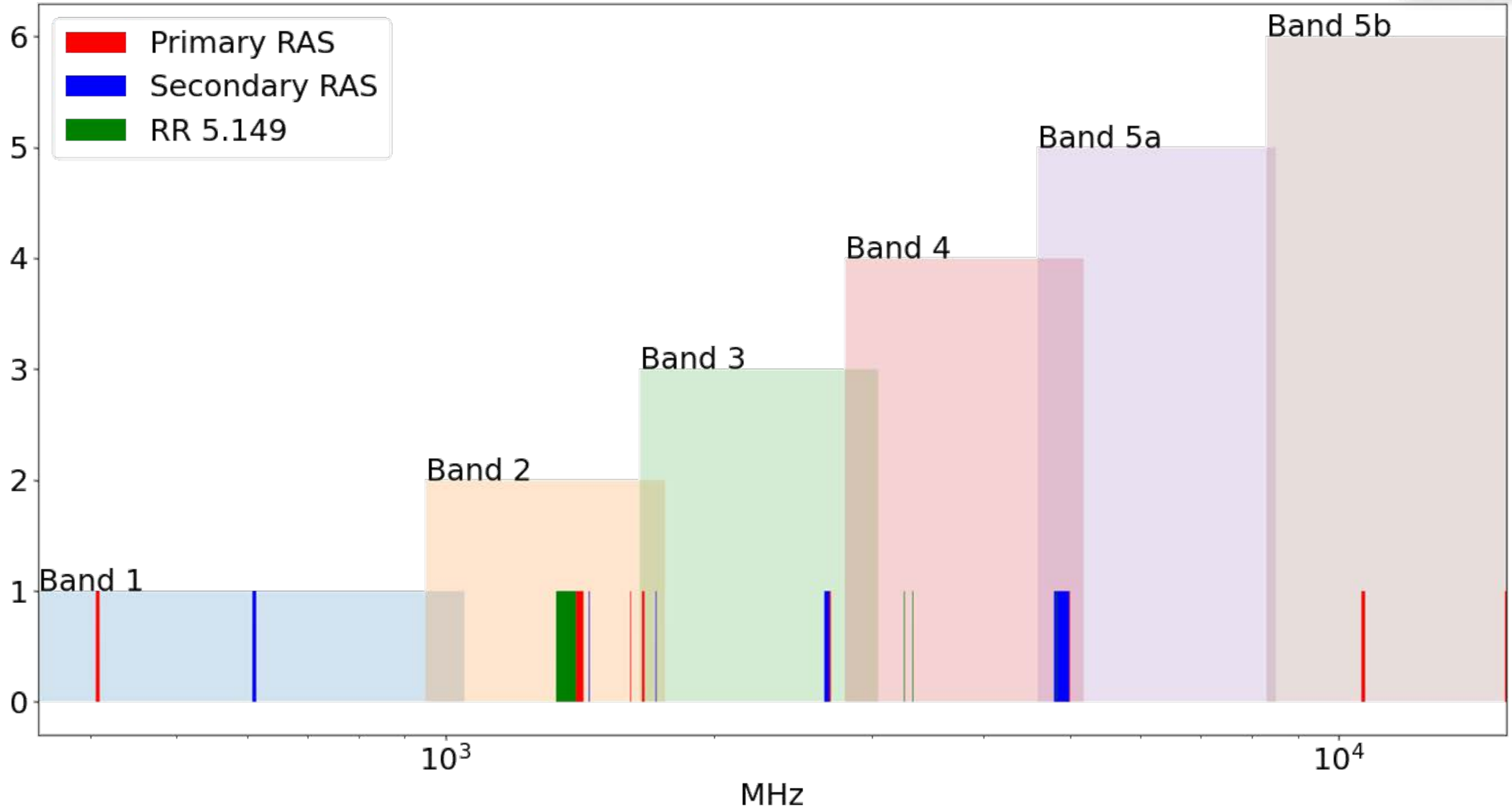
Robert Braun, Science Director

21 July 2020

Science Activity Updates

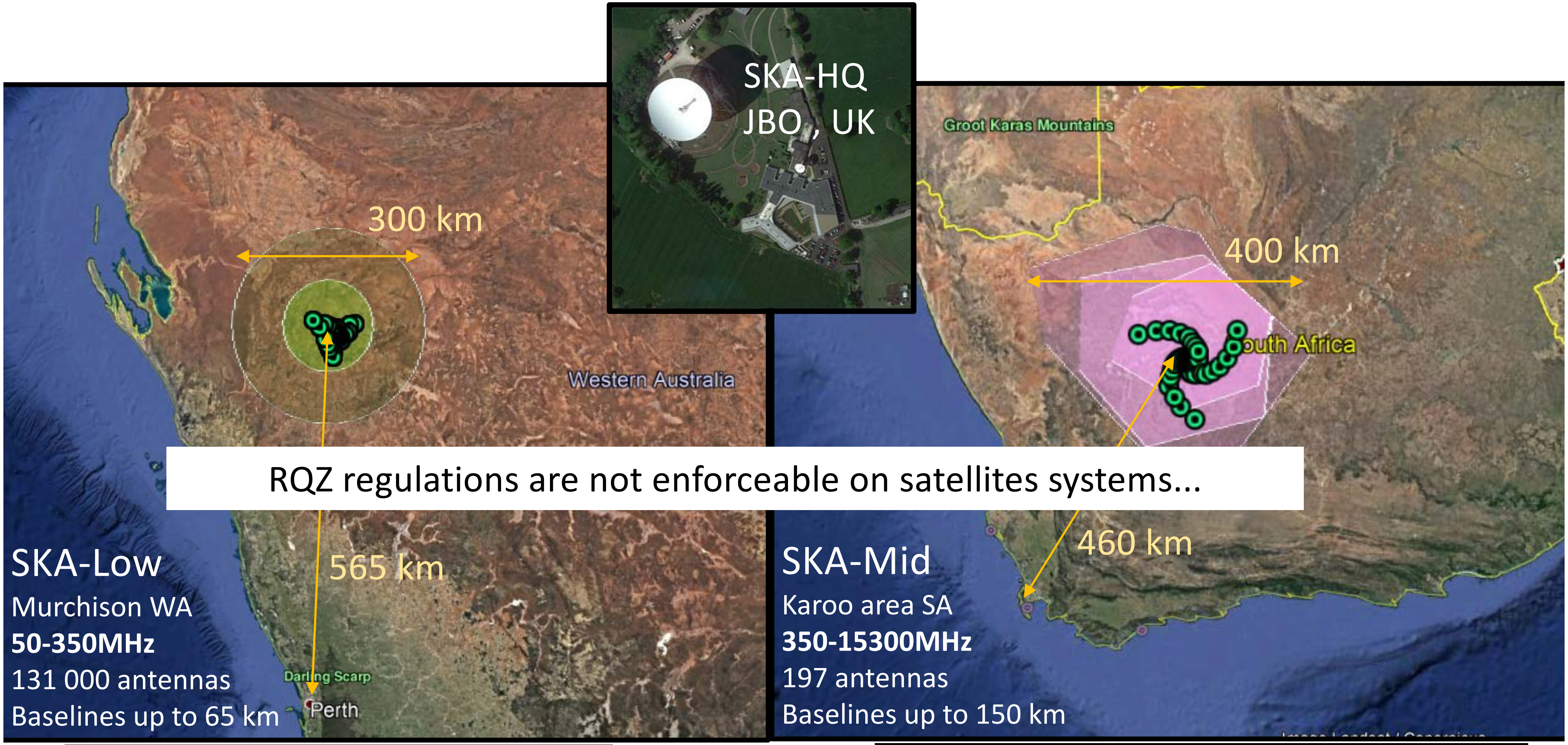
- RFI from mega-constellations
- SKA1-Low station design update (Jeff)
- SKA Observatory Development Programme (Tyler)
- AOB

RFI: What is the situation?



- RAS protected bands overlaid on SKA-Mid frequency coverage
- RQZs allow full frequency spectrum observations with low RFI
- But RQZs have limitations: Airplanes, Balloons (HAPS), Satellites

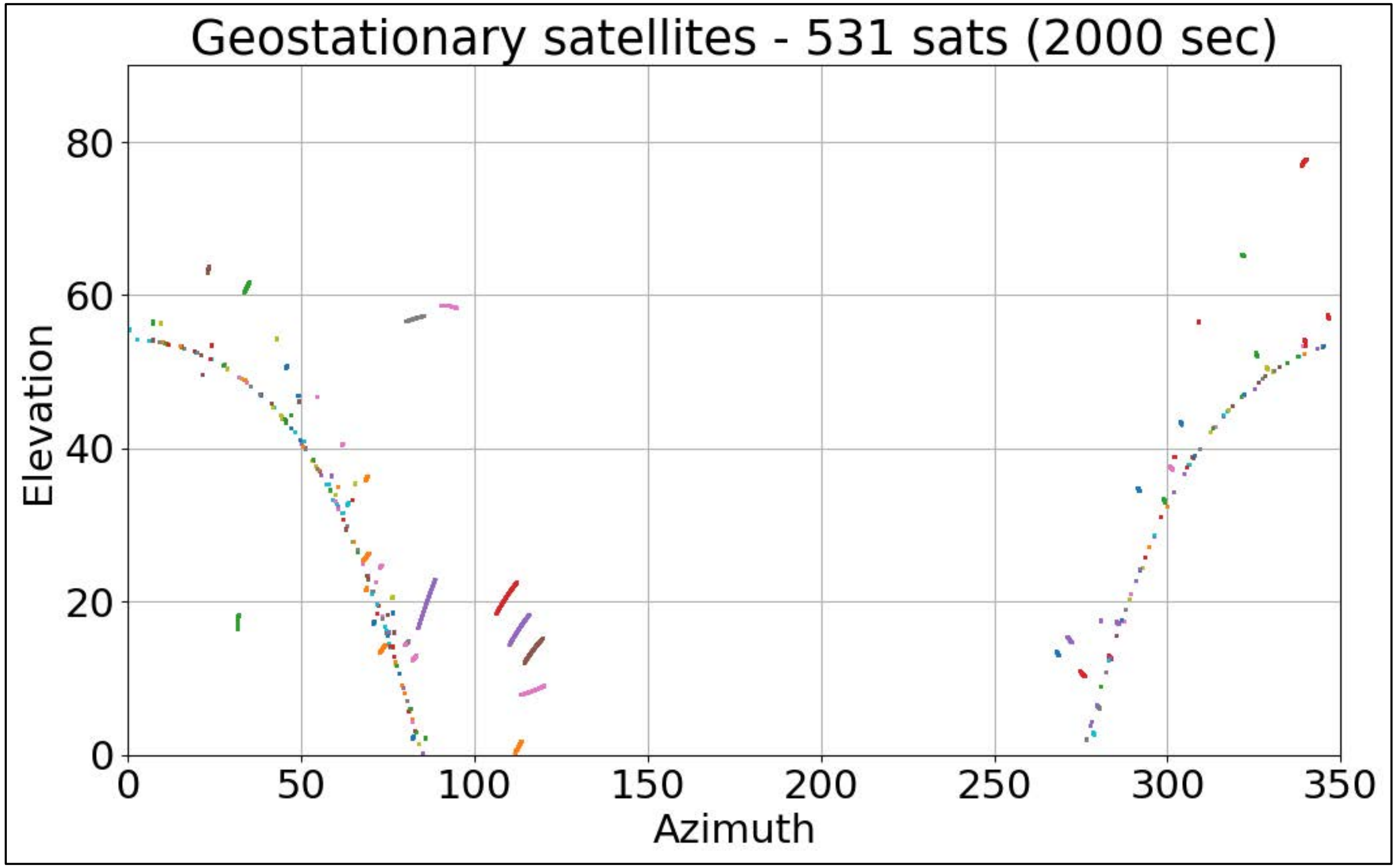
The SKA Observatory



Australian radio quiet zone Western Australia (ARQZWA)

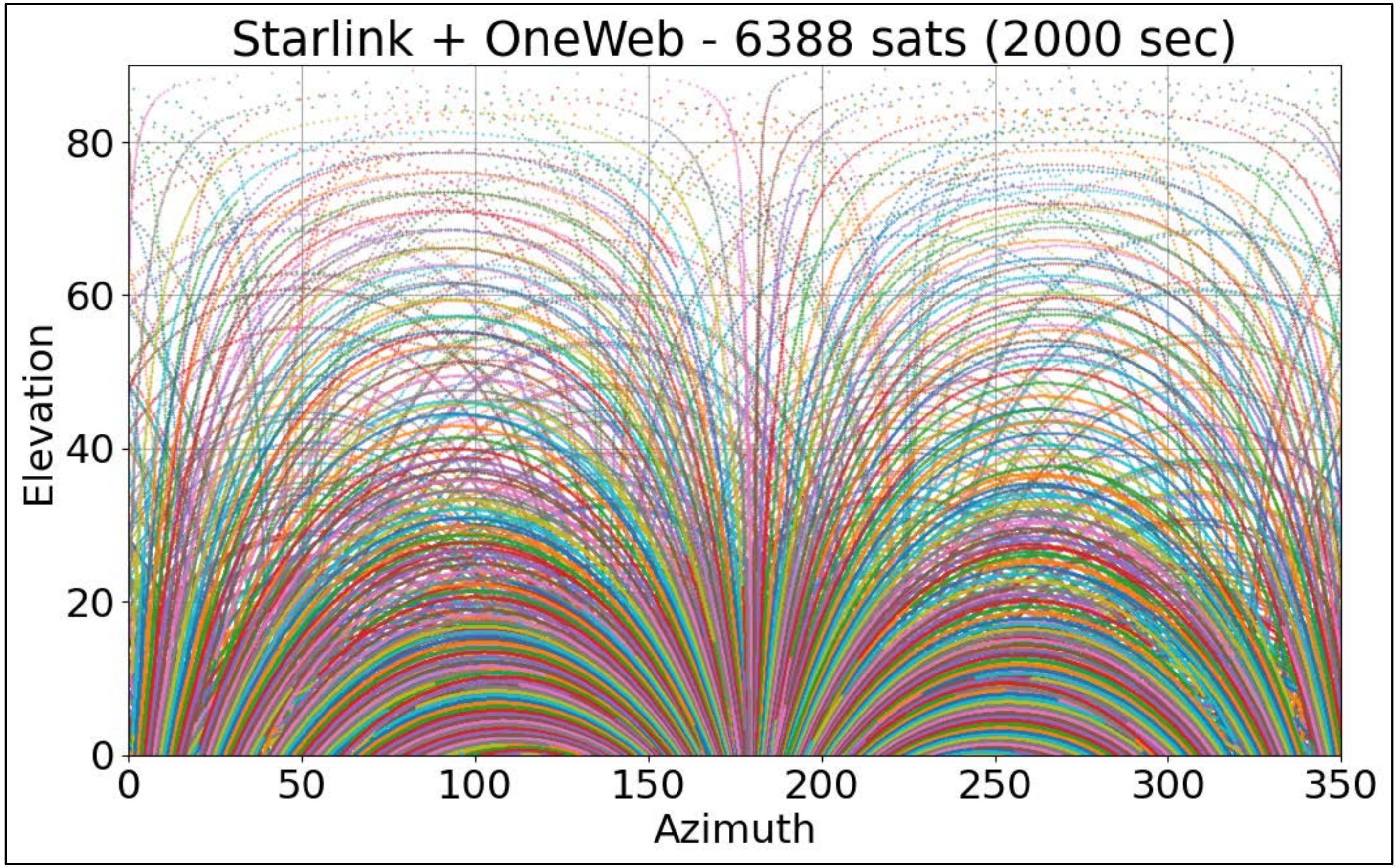
Karoo Astronomy Advantage Areas (KAAA)

RFI: What is the challenge?



- Situation in the sky is changing from ~3000 active satellites (various freqs.) to potentially >90000 (using 10.7-12.7 GHz)

RFI: What is the challenge?

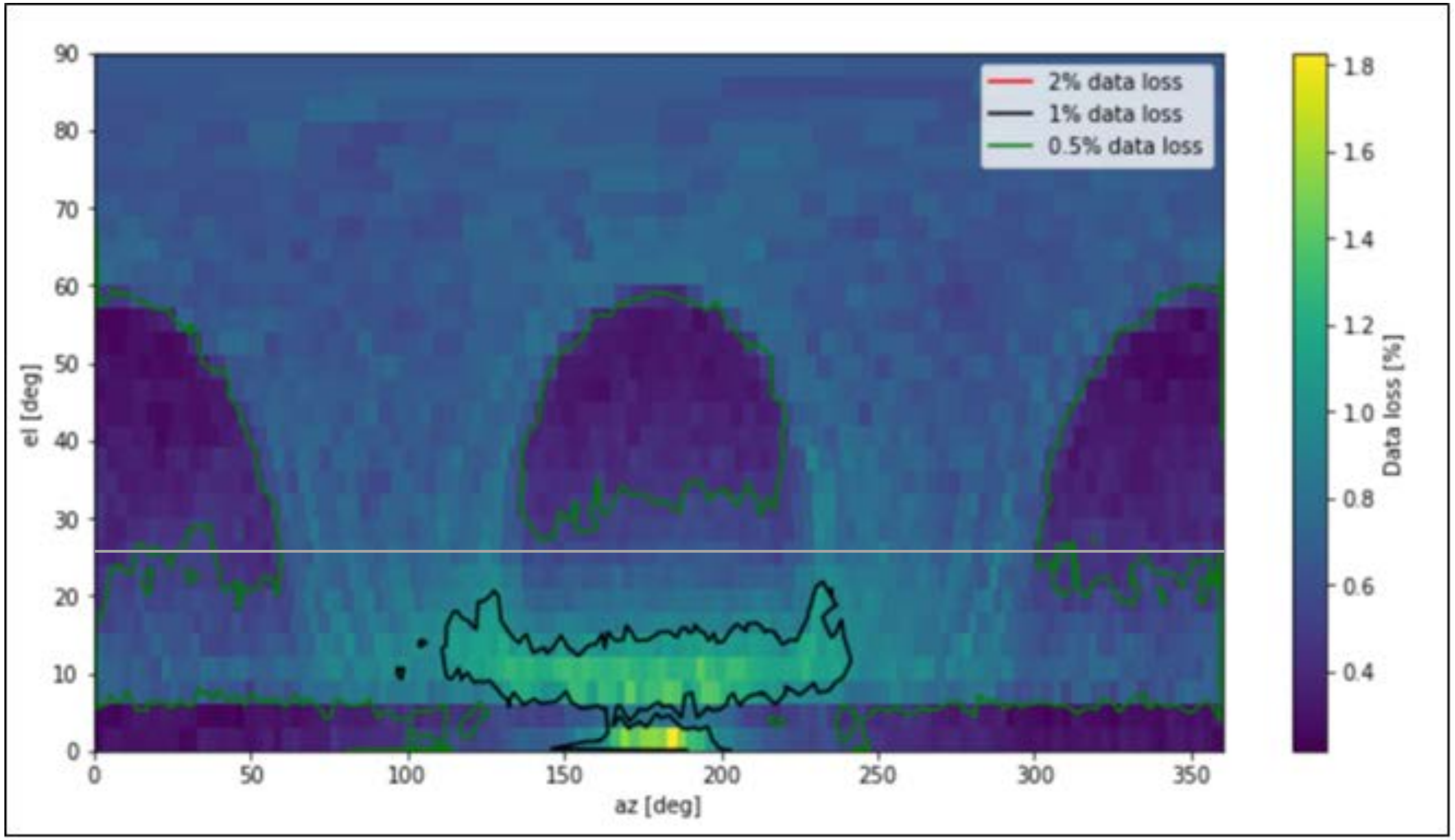


1. Engineering impact: Receiver damage? Receiver saturation?
2. Science Impact
3. Possible mitigations

RFI: Engineering impact

1. No receiver damage with assumed transmission and far sidelobe levels (in 6388 satellite case)
2. Saturation loss of Band 5B **<u>less than 2% of the time in any direction</u>**

Distribution of total loss of band 5b



RFI impact on SKA science: Spectroscopy

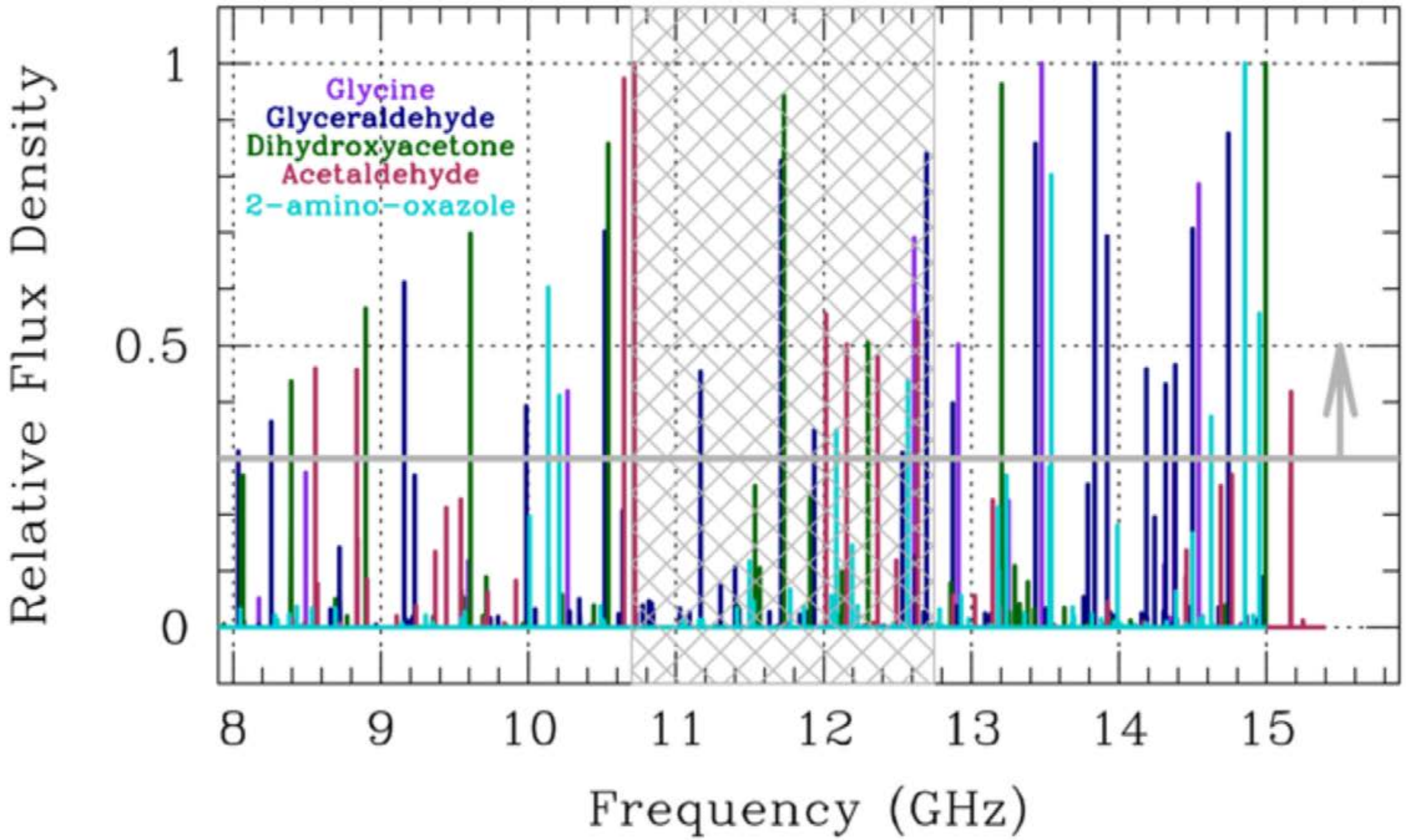


Figure 23. Spectral lines of complex organic molecules emitted in the 8 to 15 GHz range. The gray horizontal line marks the nominal SKA sensitivity limit for long integrations. The cross-hatched area, spanning 10.7 – 12.75 GHz, is directly impacted by the transmissions under consideration here.

- Complex organic molecules, possible precursors to life

RFI impact on SKA science: Spectroscopy

- Methanol masers, red-shifted molecular lines

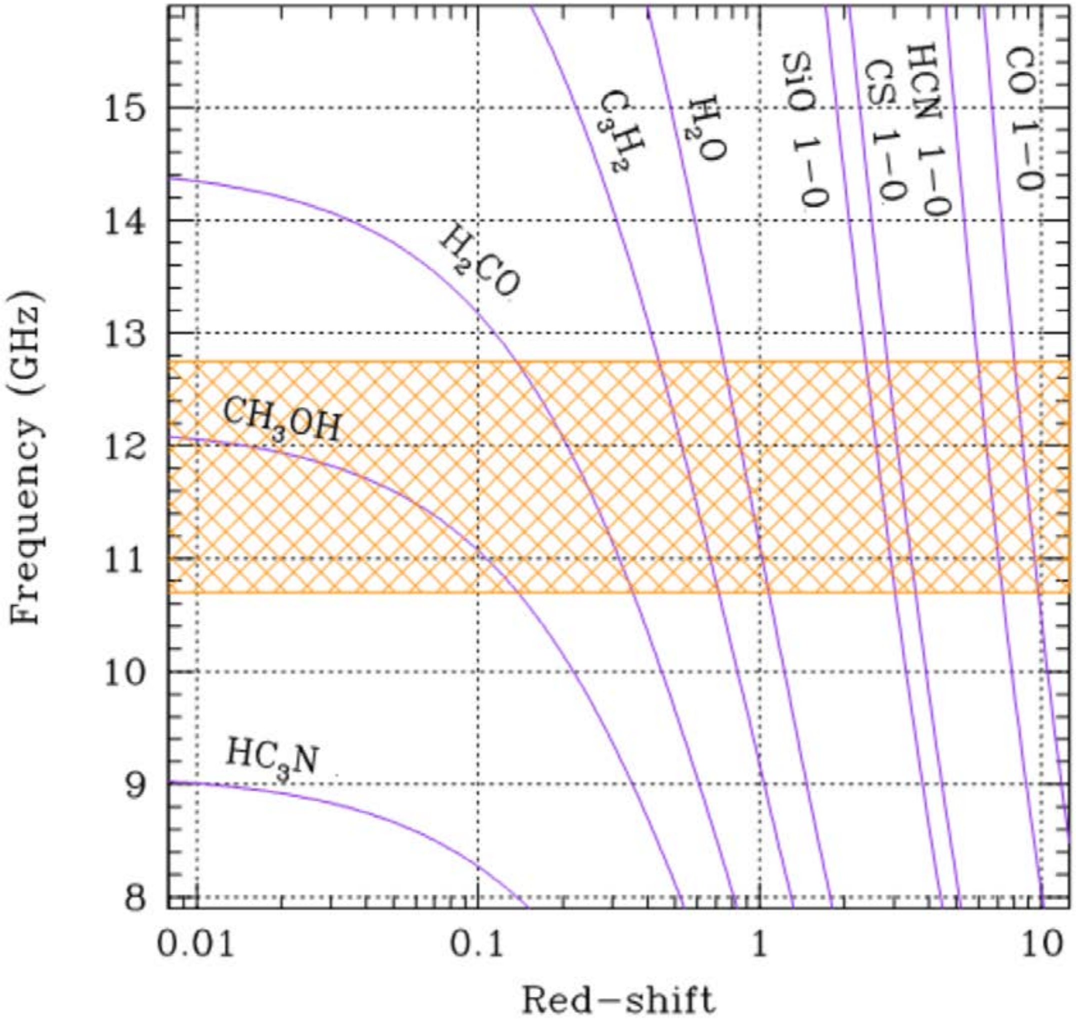


Figure 24. Important astrophysical spectral lines that are emitted within, or Doppler shifted into, the frequency coverage of the SKA Band 5b. The cross-hatched area, spanning 10.7 – 12.75 GHz, is directly impacted by the transmissions under consideration here.

RFI impact on SKA science: Continuum

- Proto-planetary disks, optically thick thermal emission

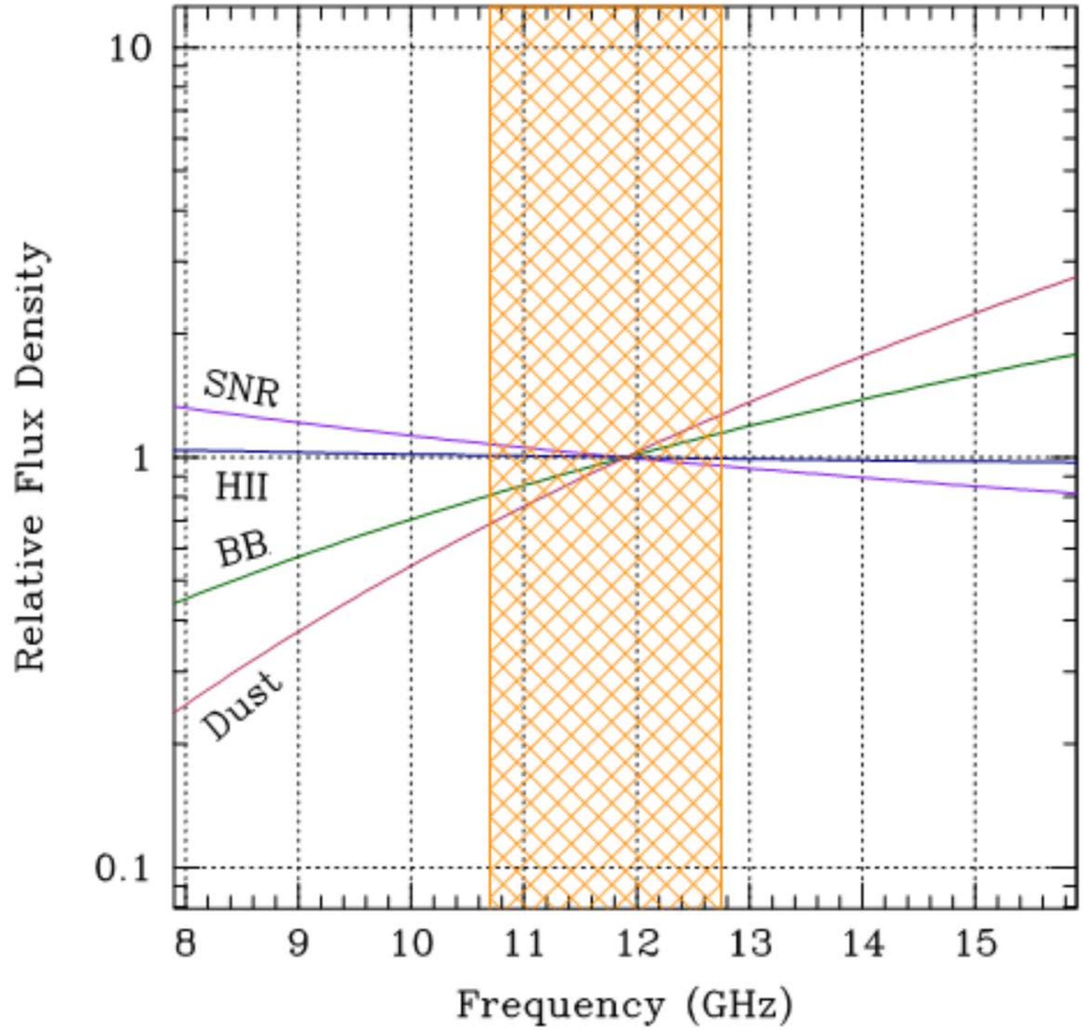


Figure 25. Nominal spectral energy curves for a range of astronomical object classes. The plotted object types are Supernova Remnants (SNR), optically thin thermal emission (HII), optically thick thermal emission (BB) and grey body dust emission (Dust). All curves are normalised to the same brightness in the band centre. The cross-hatched area is directly impacted by the transmissions under consideration here.

RFI: Impact on SKA science

- For spectral line observations, the required integration time to reach a target sensitivity will increase as the square of the effective system sensitivity
- For continuum observations the required integration time scales as the total effective bandwidth
- The engineering and science teams of the SKAO are engaging with industry to refine the assumptions used in the analysis and **precisely quantify the change** of these two parameters

RFI: Possible mitigations

- Based on early analysis, SKAO believes there are mitigation measures that would minimize the impact on our observations while having minimum impact on service availability for operators
- Engagement with industry to assess the feasibility of these measures is ongoing
- Flexibility in the pointing of satellite beams is an important factor towards possible mitigation measures

RFI: Impact of new filings

- Latest filings propose >90,000 (only Starlink and OneWeb latest FCC filings)
- If these numbers are finally deployed, observations with wideband receivers (containing mega constellations downlink bands) will be extremely challenging
- Mitigation measures will be necessary to allow radio astronomy to continue its breakthrough science (within this frequency bands). A strong commitment from industry and governments is needed.

Update on SKA1-LOW station design work

ASTRON, Cambridge, CSIRO, Curtin INAF, KLAASA, U. Malta, NCRA, SKAO

- AAVS2 test results and simulation meeting June 23-24:
  - Updates on (SKA1-LOW) system and station simulations
  - Calibration and stability measurements from AAVS2/EDA2
  - Beamforming drift scan and pointed tracking results
  - Sensitivity of AAVS2
  - Test pulsar observations
  - Polarization (IXR) analysis

SKALA4.1
Log periodic antenna

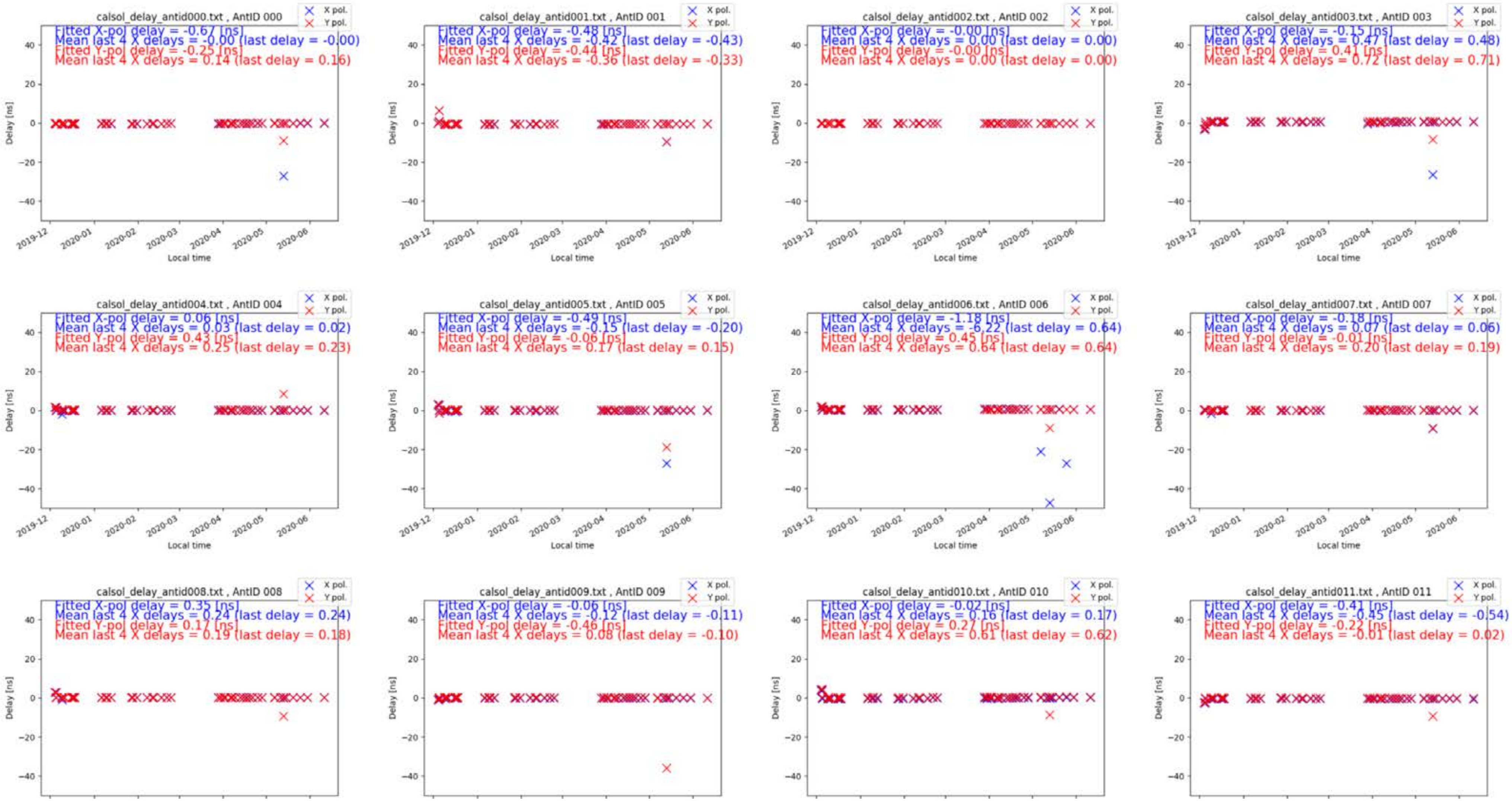
Update on SKA1-LOW station design work

ASTRON, Cambridge, CSIRO, Curtin, INAF, KLAASA, U. Malta, NCRA, SKAO

- Array level simulations completed including station beamforming errors, ionosphere – what are the effects on images?
- Simulated embedded element patterns for SKALA4.1 antennas available at: 50, 55, 80, 110, 140, 160, 210, 220, 230, 280, 340, 345, 350 MHz (upon request)
- AAVS2: delay-based calibration solutions derived using the Sun (many frequencies) stable over 24 hours
- Zenith sensitivity of AAVS2 meets SKA1 requirements at 110 and 160 MHz
- Simulations of polarization (IXR) properties of SKALA4.1 antennas demonstrate compliance with requirements (>100 MHz)

Update on SKA1-LOW station design work

ASTRON, Cambridge, CSIRO, Curtin, INAF, KLAASA, U. Malta, NCRA, SKAO



AAVS2 sun-based delay calibration solution stability

Wayth et al.

Update on SKA1-LOW station design work

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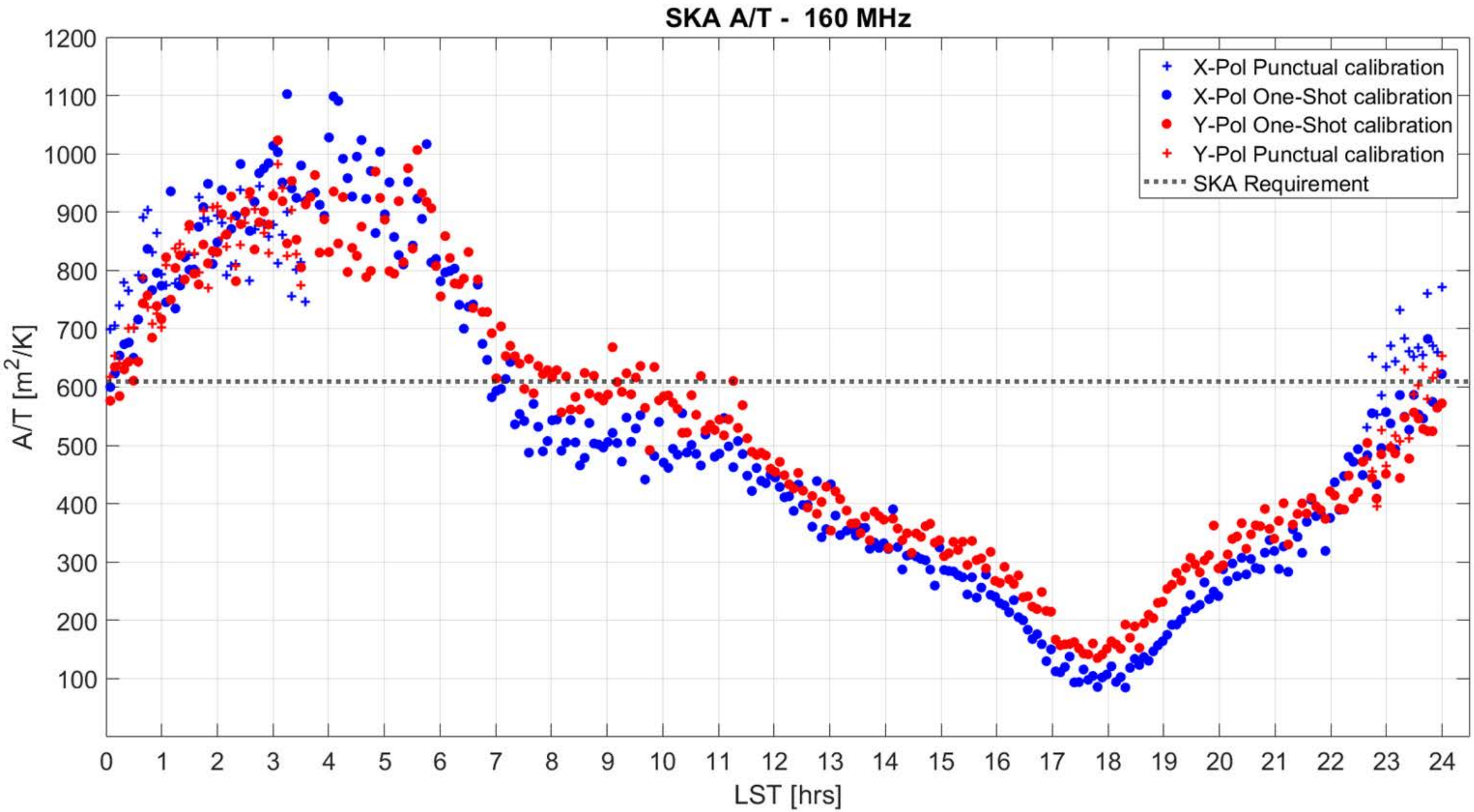

Bernardi et al.

Update on SKA1-LOW station design work

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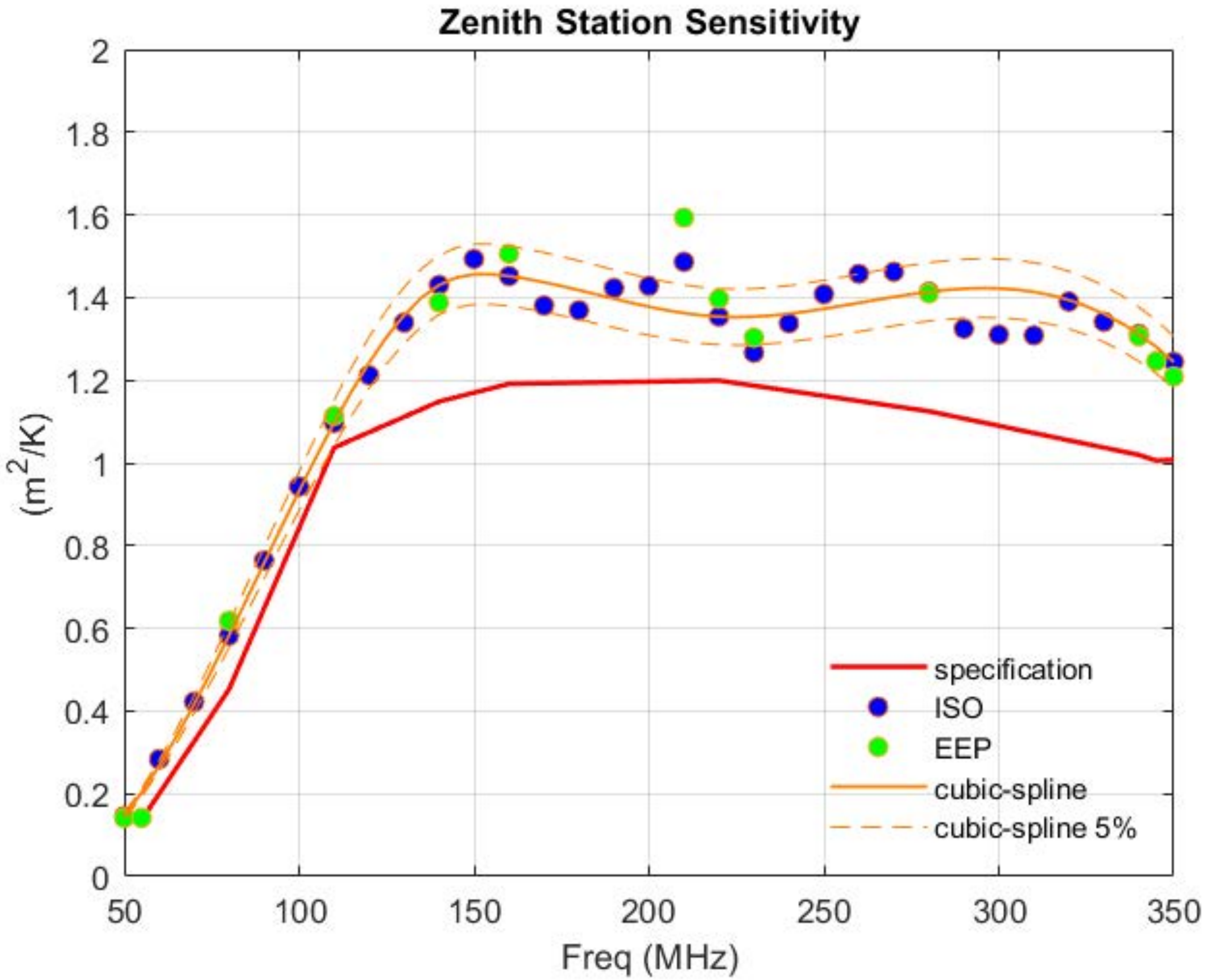

Station simulations

- SKALA4.1 EEPs
- Simplified sky model:

$$T_{sky} = 20\left(\frac{0.408}{f_{GHz}}\right)^{2.75} + 2.73 + 288\left(0.005 + 0.1314e^{8[\log(f_{GHz})-\log(22.23)]}\right)$$

- No coupling effects

Bolli et al.

Rationale for Observatory Development Programme (ODP)

- Enhance SKA Science Output
  - Adapt to changes in scientific landscape and priorities
  - Enable new science (e.g. a new receiver band)
  - Improve science output (e.g. more reliable power system; increased RF bandwidth)
  - Reduce operations costs
  - Restore lost capability

- Enabled by
  - **Projects** to deliver major improvements
  - **Studies** to evaluate new ideas and bring them to an adequate Technology Readiness Level (TRL) to become potential projects in the future

- Supported by
  - Prioritisation of R&D
  - **Science and technology road-maps**
  - Development of new ideas to the level that they enable more and better science

SKAO is not resourced to be a funding agency for blue-sky R&D

A Development Programme is essential to the health of any Observatory

Road Maps and Development Plan

- **Science Road Map**
  - New science enabled by ODP
  - External Advisory Group Chaired by Science Director
  - Maintains a list of science opportunities and priorities

- Technology Road Map
  - Survey of new technology relevant to SKA
  - External Advisory Group Chaired by Project Engineer
  - Surveys new technological opportunities, with a rough assessment of TRL and cost

- Development Plan
  - Evolving Plan for the ODP, informed by the road maps
  - Balances restoration of capability (if required) against new ideas
  - External Advisory Group Chaired by SKAO System Scientist
  - Plan presented to SEAC for approval
  - Circulated to the wider SKA Community

Studies

- Needed to prepare project proposals
- 2 or 3-year funding cycle
  - Open call for proposals
- Scope
  - Small-scale feasibility studies, algorithms etc.
  - Preparation for large projects
- Light touch Management within SKAO

Projects

- Deliver a major increment in capability
  - Duration 1 – 5 years
  - Budget up to ~€20M (e.g. receiver band)
- Project proposals in response to a directed call
  - Expected to be on the road-map
  - Balance of size, science, efficiency improvement, restoration of descoped capability and new opportunities
  - Mandatory science case; PM, systems engineering, test, QA plans
- Selection
  - Rigorous management (Science + Technical + Programmatic assessments by SKAO)
  - SEAC review

Initial Budget Profile

- Current baseline (direction from Board & CPTF)
  - €40M over 10 years from Construction start
  - €20M per annum in steady state

- Rationale for funding profile
  - Long lead times and maintaining momentum in the community both argue for an early start to studies
  - Need to manage the study programme during construction
    - Keep it simple
  - Major projects not feasible until after the end of construction
  - Phased to restore capability as necessary

Timetable – example only

Year	Cost (M€)	Activity
1	0	Road map and plan process starts
2	0	Initial draft road maps and development plan made available by SKAO. Deadline for Study Cycle 1 proposals
3	1	Study cycle 1
4	1	Study cycle 1 (continued); Deadline for Study cycle 2 proposals
5	1.5	Study cycle 2
6	1.5	Study cycle 2 (continued); Deadline for Study cycle 3 proposals
7	1.5	Study cycle 3 (project preparation)
8	1.5	Study cycle 3 (continued); Approved Development Plan available. Deadlines for Study cycle 4 and Project cycle 1
9	12	Project Cycle 1
	1	Study cycle 4
10	18	Project Cycle 1 (continued)
	1	Study Cycle 4 (continued)
11+ (steady state)	18.5	Projects
	1.5	Studies

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www.skatelescope.org