ITALIAN DEVELOPMENT FOR SKA-Low

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SQUARE KILOMETRE ARRAY

- *Huge* science project: 100 organizations in 20 countries
- *Biggest* radio interferometer: km-square collecting area, thousands km extension
- Built in *remote* deserts (radio-quiet/good atmospheric conditions)

History of INAF participation to SKA

LFAA CDR

SCDR

PRR

Dawn project	BEST era	Middle age	Renaissance

2002
First SKA meeting

2004
Preparation requests UE – FP6-SKADS

2005–2009
SKADS

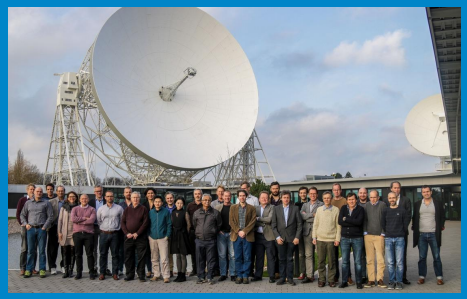
2010–2015
AAVP

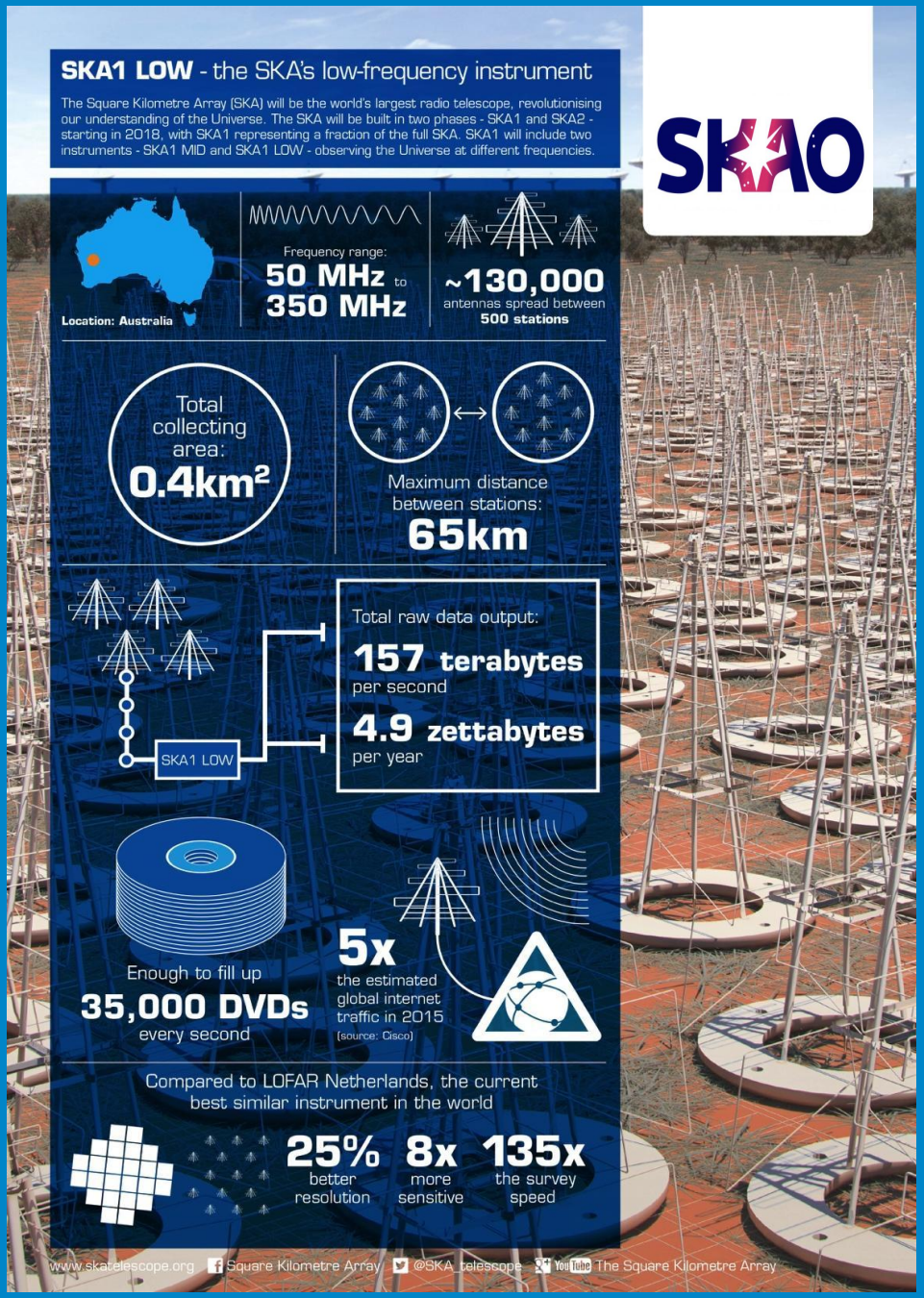
2015-2018
AADC-RT

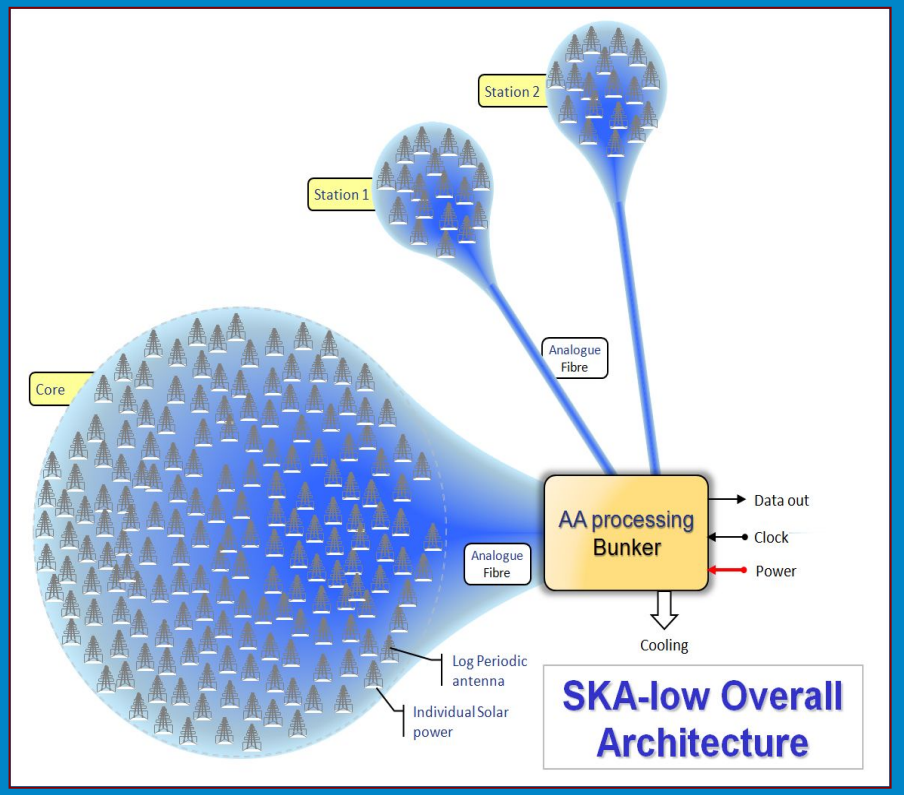
2018-2022
Bridging phases
Pre-procurement

2018-2022
Bridging phases 1-2-3
Pre-procurement

2023-2028
AA0.5-AA3*

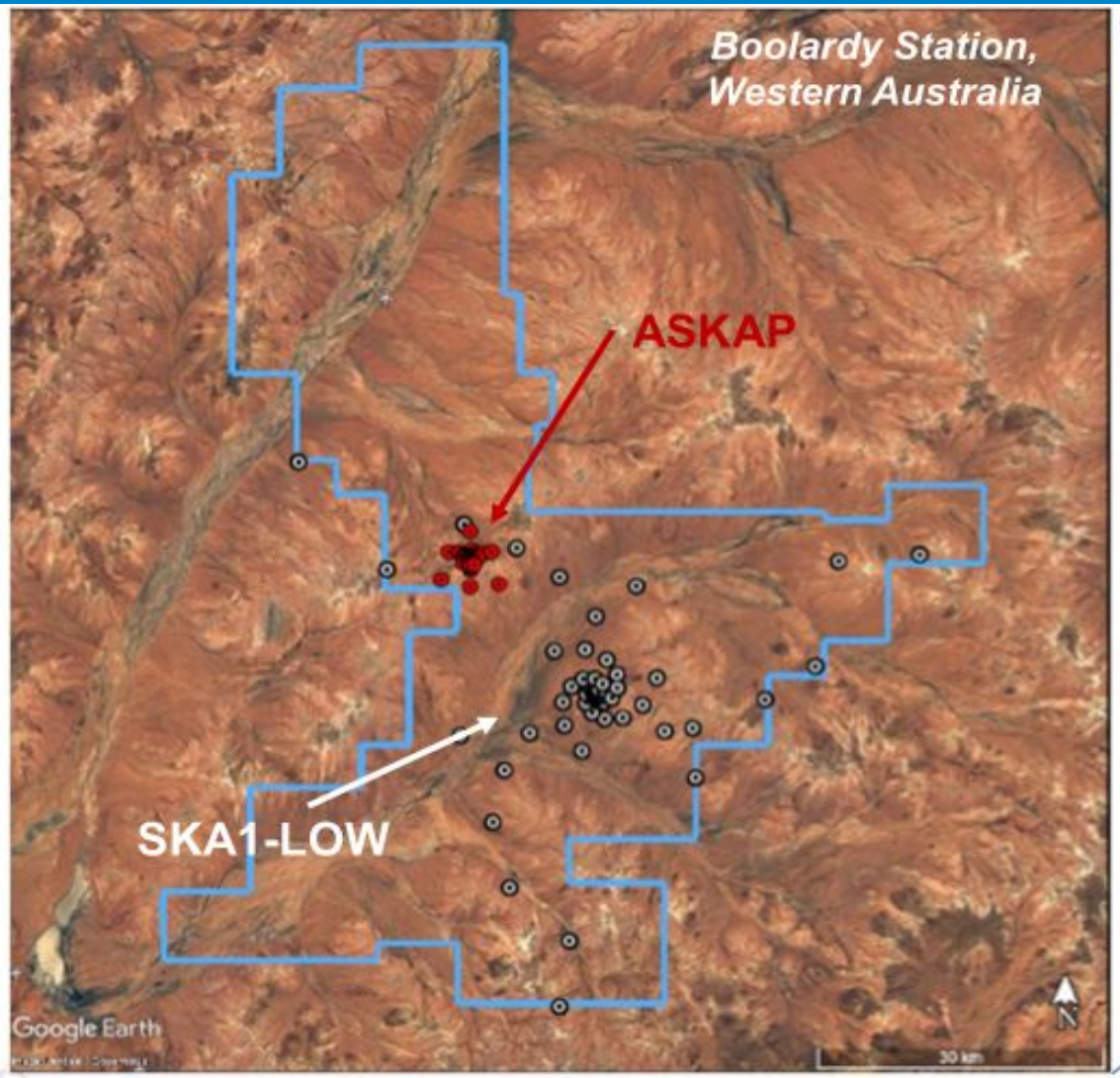




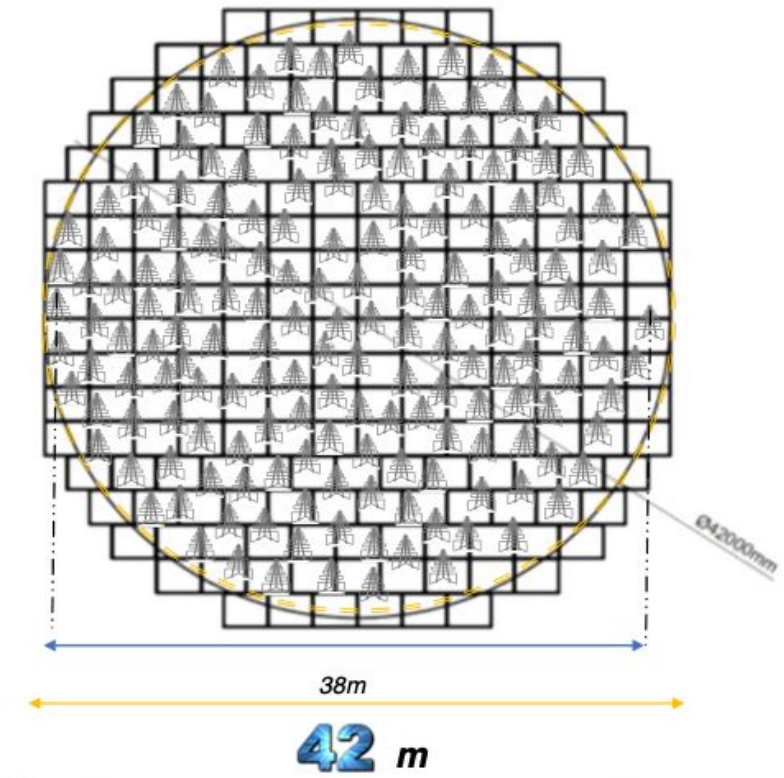


512 stations, 38m (256 antennas)

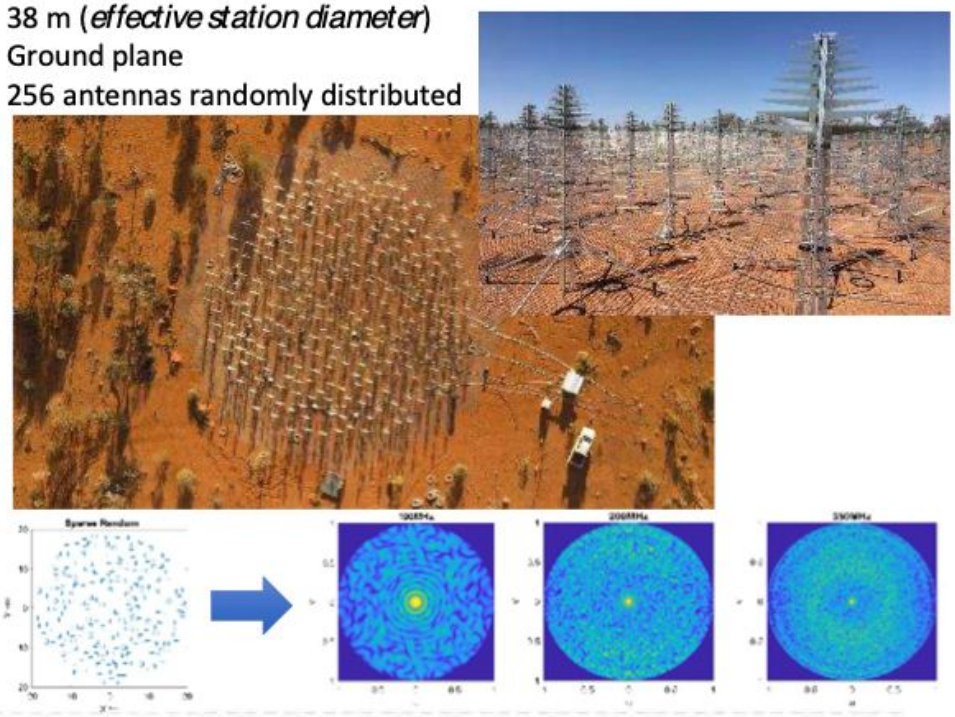
SKA1-Low configuration



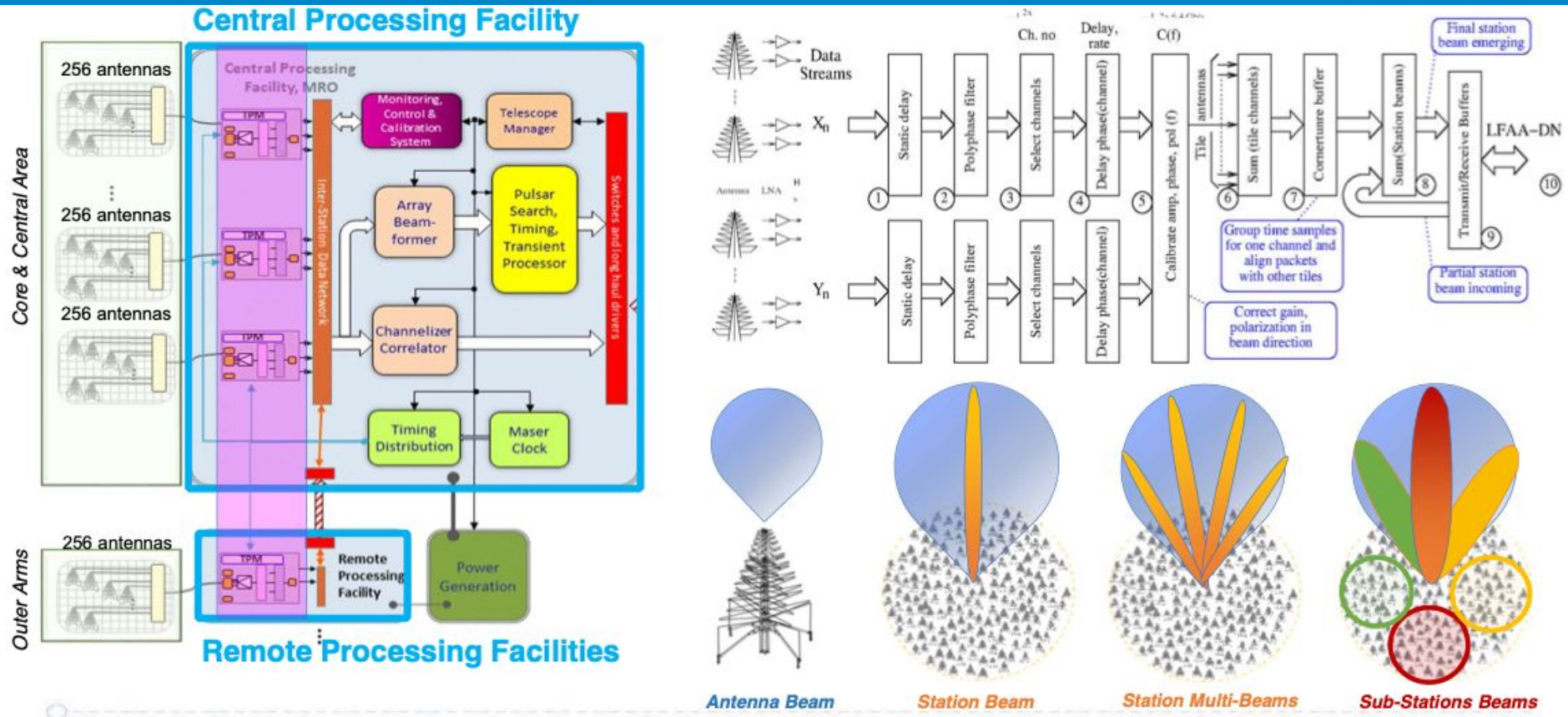
Field station



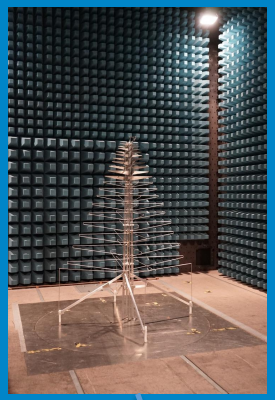
- 256 antennas
- Circular area
- 38 m (*effective station diameter*)
- Ground plane
- 256 antennas randomly distributed

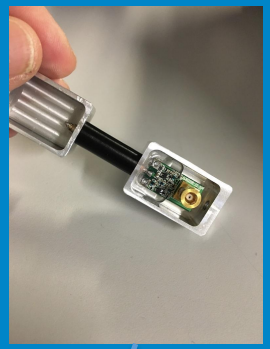


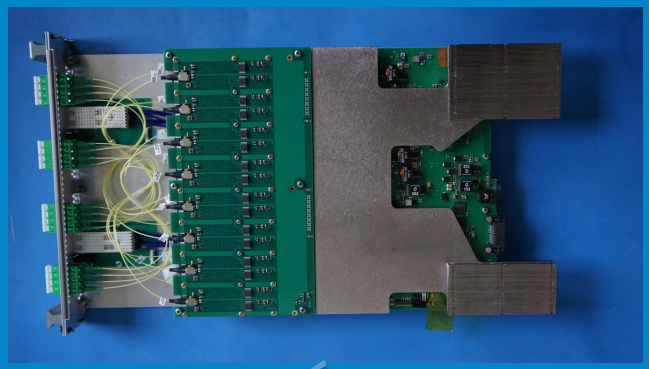
SKA1-Low architecture: station beamformer

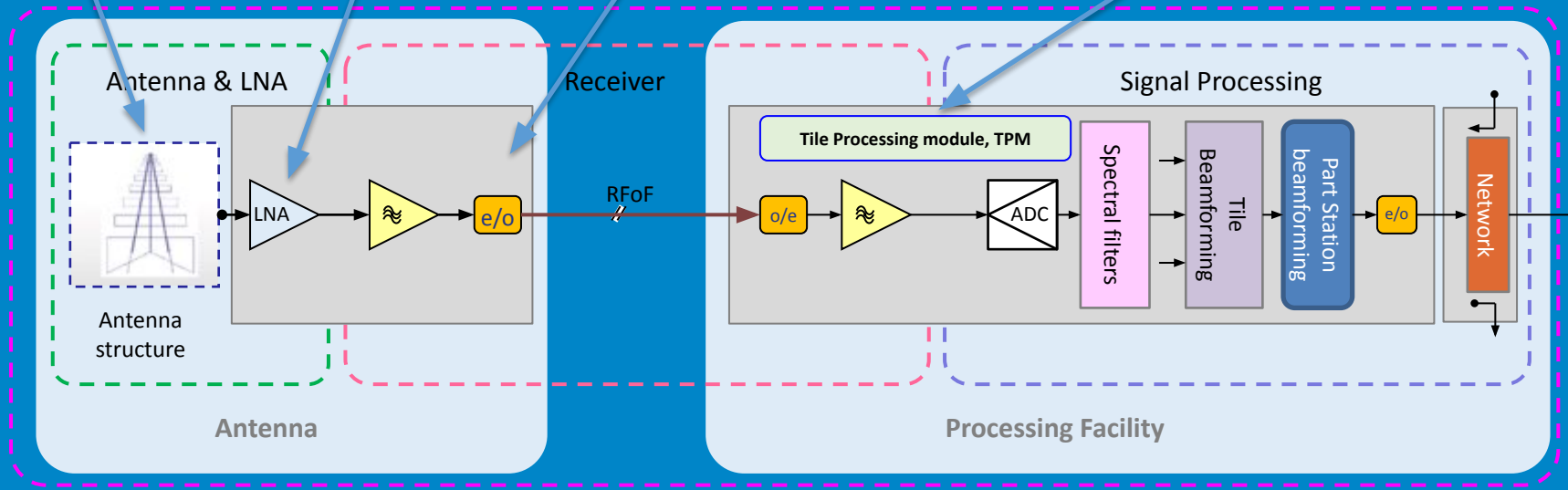


Receiver chain: technology made in Italy



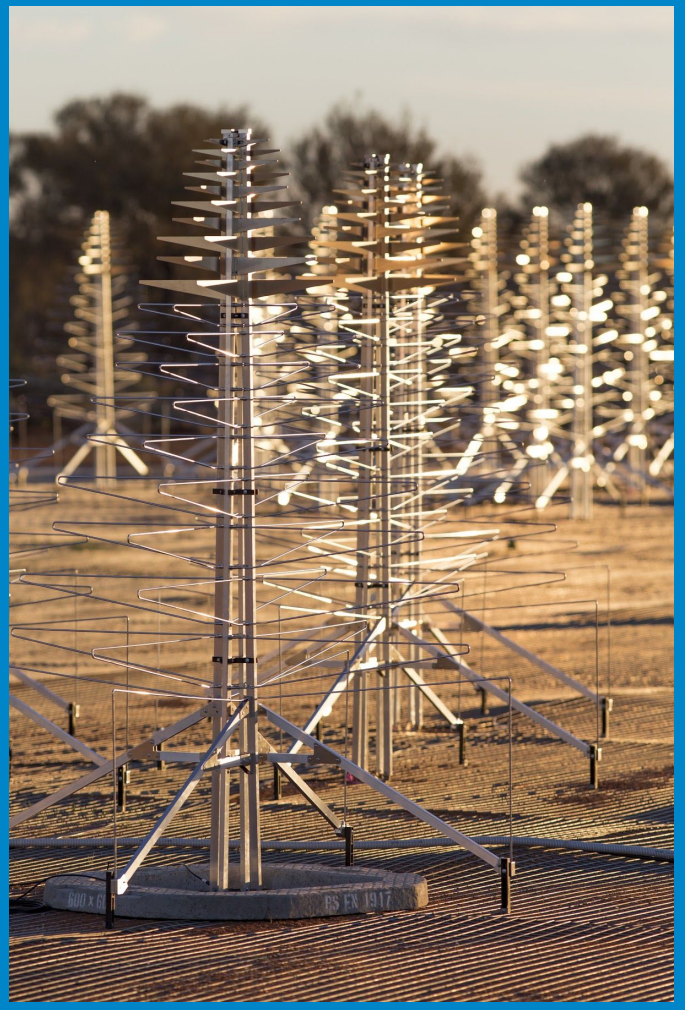






SKALA4.1AL Antenna

- Dual-polarized LPDA.
- 20 dipoles: 19 triangular-tooth plus 1 bow-tie at the bottom of the antenna.
- Solid dipoles on the high-frequency elements and wire dipoles on the low-frequency ones.
- 1-degree tilted boom.
- Aluminium-made.
- Electrical connection of the antenna to the ground plane.
- Antenna matched to a single-ended 50-ohm LNA.
- LNA encapsulated in the top-cap of the antenna and connected to a coaxial cable embedded in the antenna booms.

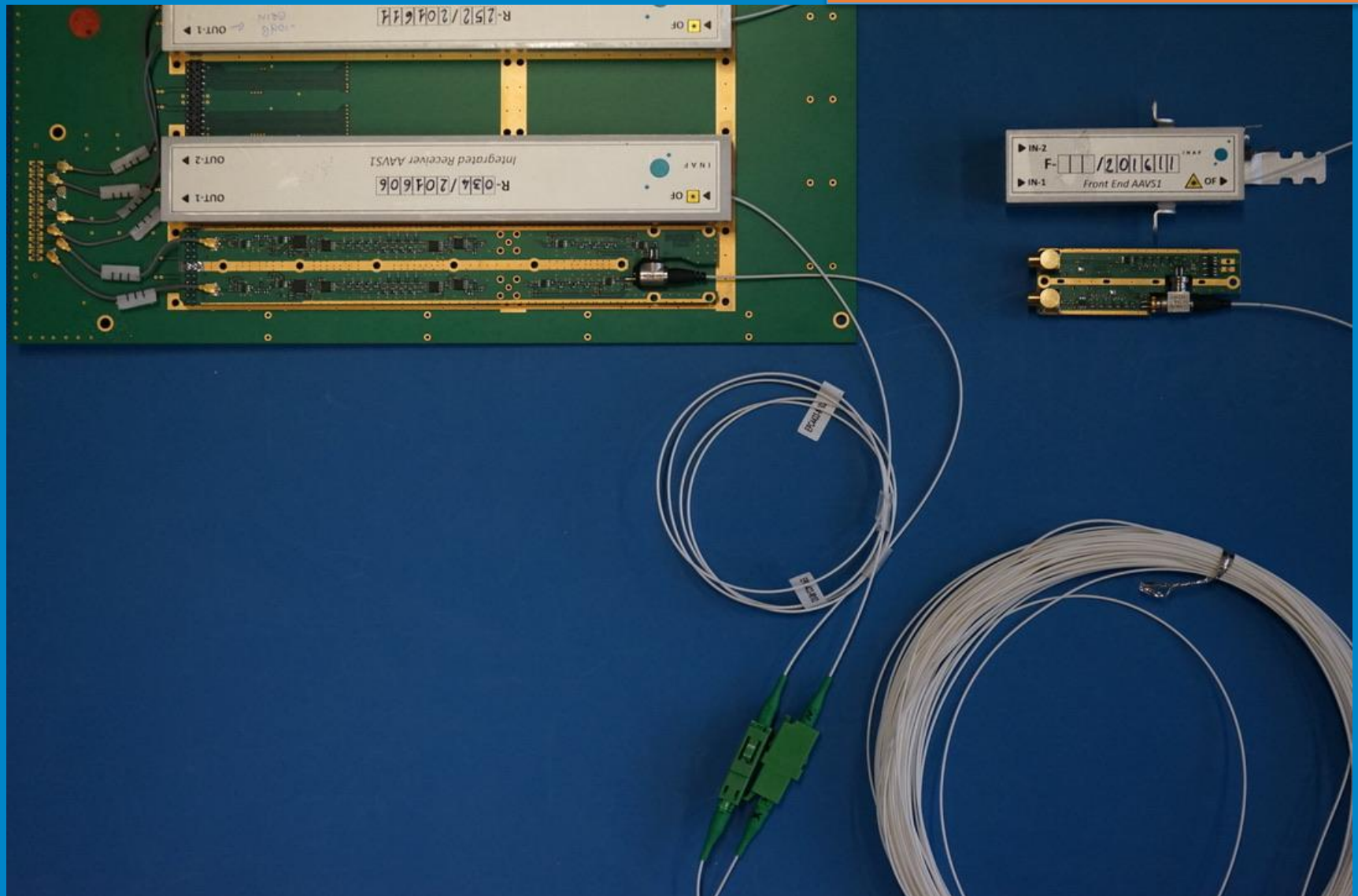


Analogue RFoF link

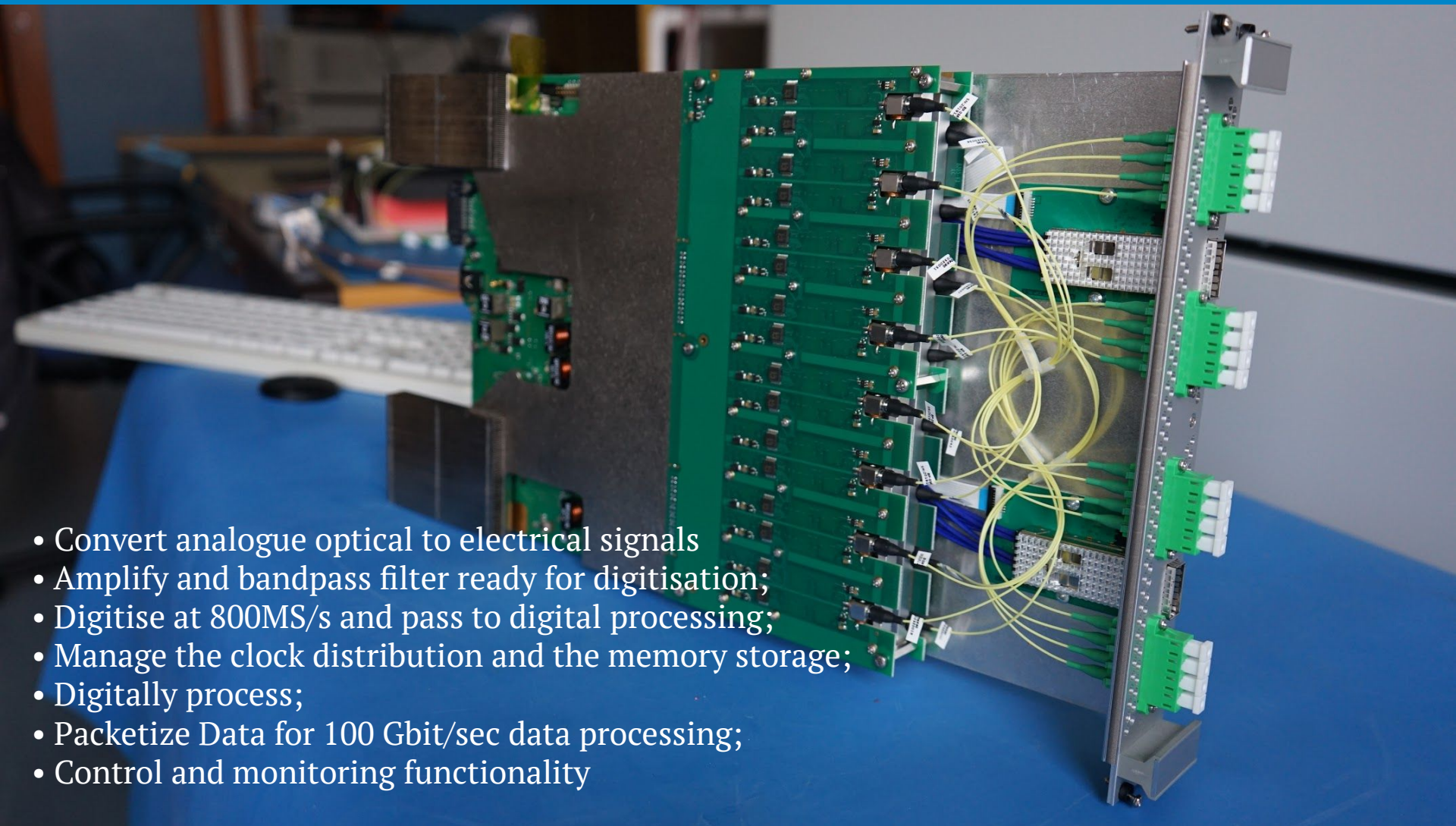
OPTEL
OPTOELETTRONICA TELECOMUNICAZIONI

MEDICINA RADIO ASTRONOMICAL STATION

PROTECH ENGINEERING



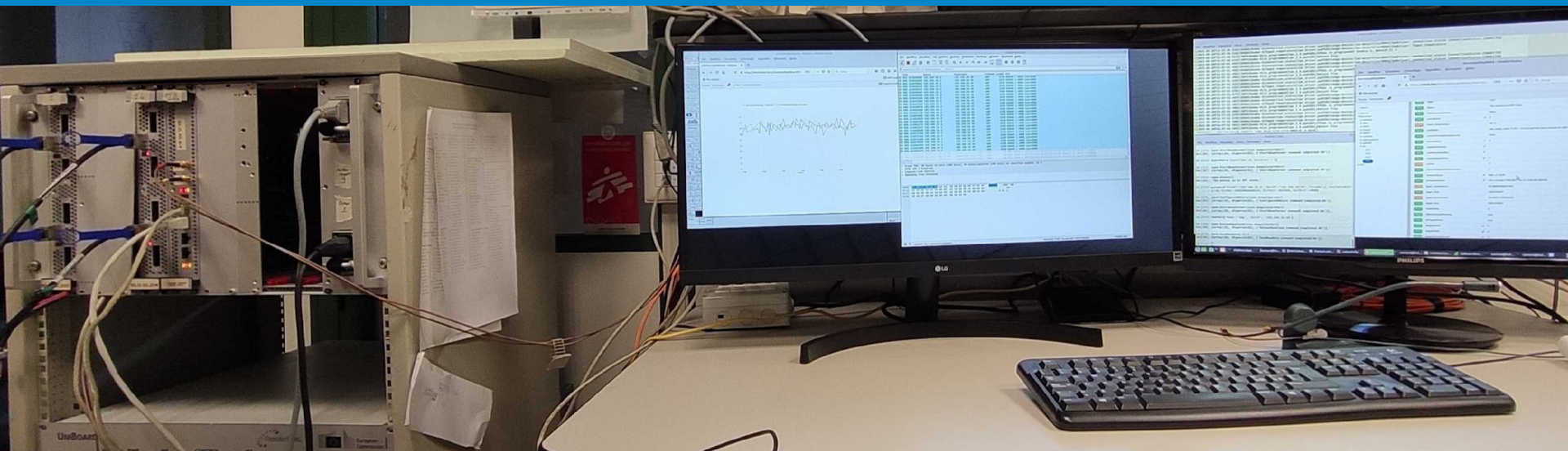
Tile Processing Module



- Convert analogue optical to electrical signals
- Amplify and bandpass filter ready for digitisation;
- Digitise at 800MS/s and pass to digital processing;
- Manage the clock distribution and the memory storage;
- Digitally process;
- Packetize Data for 100 Gbit/sec data processing;
- Control and monitoring functionality

Firmware

- LFAA firmware used in the iTPM board to
  - Channelize, calibrate and align antenna signals
  - Combine 256 antennas in up to 48 beams
  - Format and transmit beamformed signals to correlator
  - Format and transmit selected signals to calibration server
- Prototype firmware used in AAVS array
- Significant work required for industrial grade final system
- People: 3 persons (1 FTE) INAF, 4 persons (3 FTE) UK



Software

- Low level control software
  - Hardware drivers: developed together with firmware blocks
  - General standalone software, used at AAVS array
  - Control of cabinet and subrack electronics (power management, temperature, cooling)
- Integration of hardware in SKA Low LMC
  - Device software in the Tango Control environment
  - Hardware related problems: antenna pointing, beam management, observation management, calibration strategies
  - Interface with other systems (correlator, telescope manager)
  - Network design and management (SKA as a network defined instrument)

UAV

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Australian Outback

Murchison Radio Observatory

MWA :
Murchison Widefield Array

AAVS1:
Aperture Array Verification System 1

EDA2 and AAVS2

2 demonstrators built at MRO site to verify SKA1-low system before construction

EDA2 (2019)
256 **MWA dipoles**
LNA modified for
50-350 MHz
35 m diameter

AAVS2 (end of 2019)
256 **SKALA 4.1** log-periodic
LNA optimized for
full **50-350 MHz**
38 m diameter

Aerial view of EDA2 and AAVS2 - Credits: Icrar/Curtin

INAF Observation WG: First results and future work

OAArcetri - G. Macario, P. Bolli, P. Di Ninni, G. Comoretto

IRA - G. Bernardi, G. Pupillo, F. Perini, A. Mattana, J. Monari

+

support to/validation of AAVS2 commissioning observations

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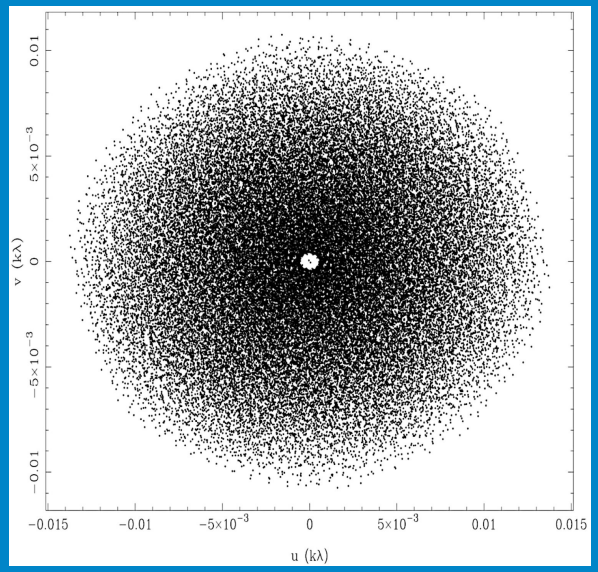
support to/validation of AAVS2 commissioning observations

"Golden datasets" of parallel AAVS2/EDA2 acquisitions:

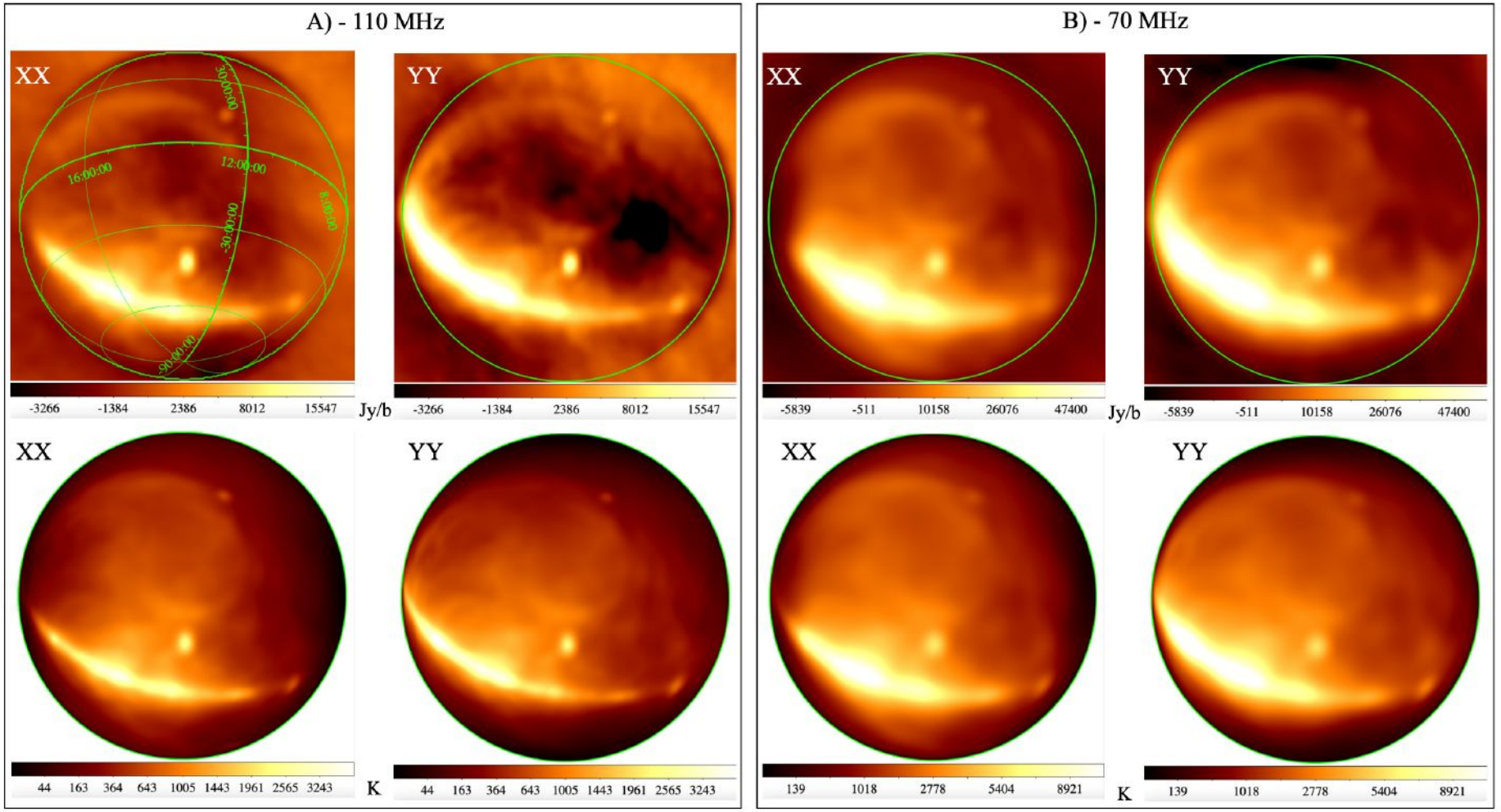
- 50, 70, 110, (137), 160, 230, 320 MHz (based on UAV)
- started in 12/2019, stable since 02/2019
- *snapshots* every 5 minutes, across ~24-48 hours LST

(t_{int}=0.14s, ~1 MHz BW, main purpose: sensitivity)



AAVS2 single snapshot uv-coverage at 110 MHz (Sun transit)

1. Sun-based calibration and all-sky imaging



Macario, Pupillo, Bernardi et al. 2021 (Astro-ph)

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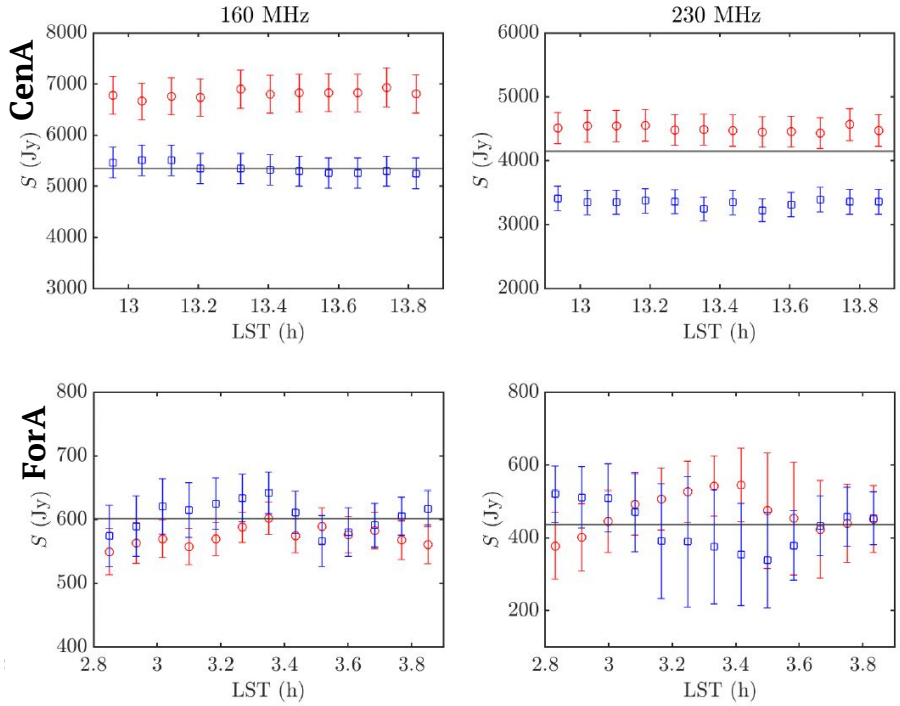
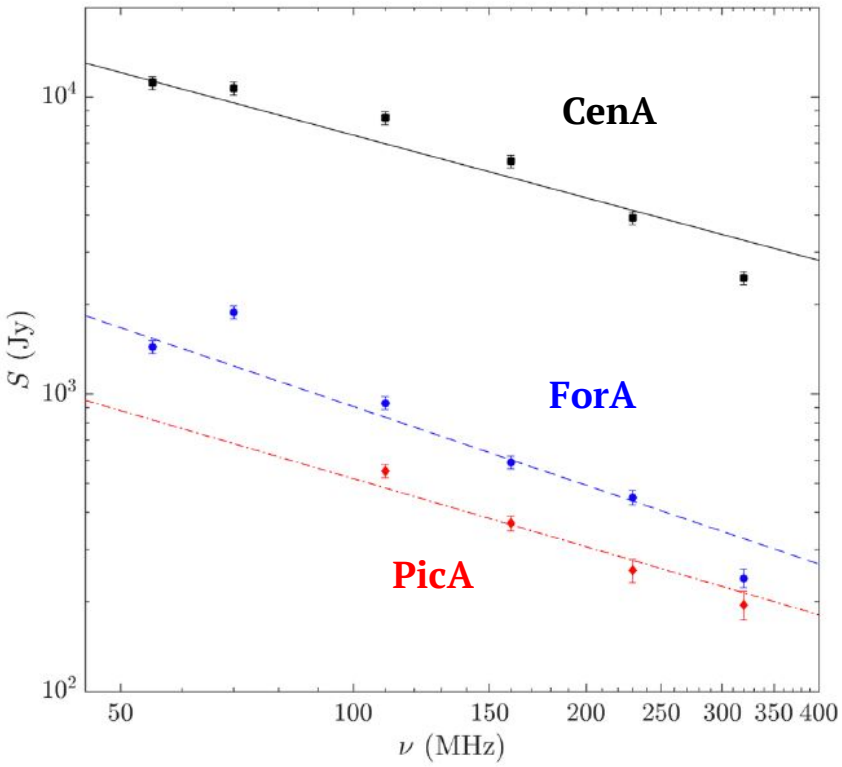


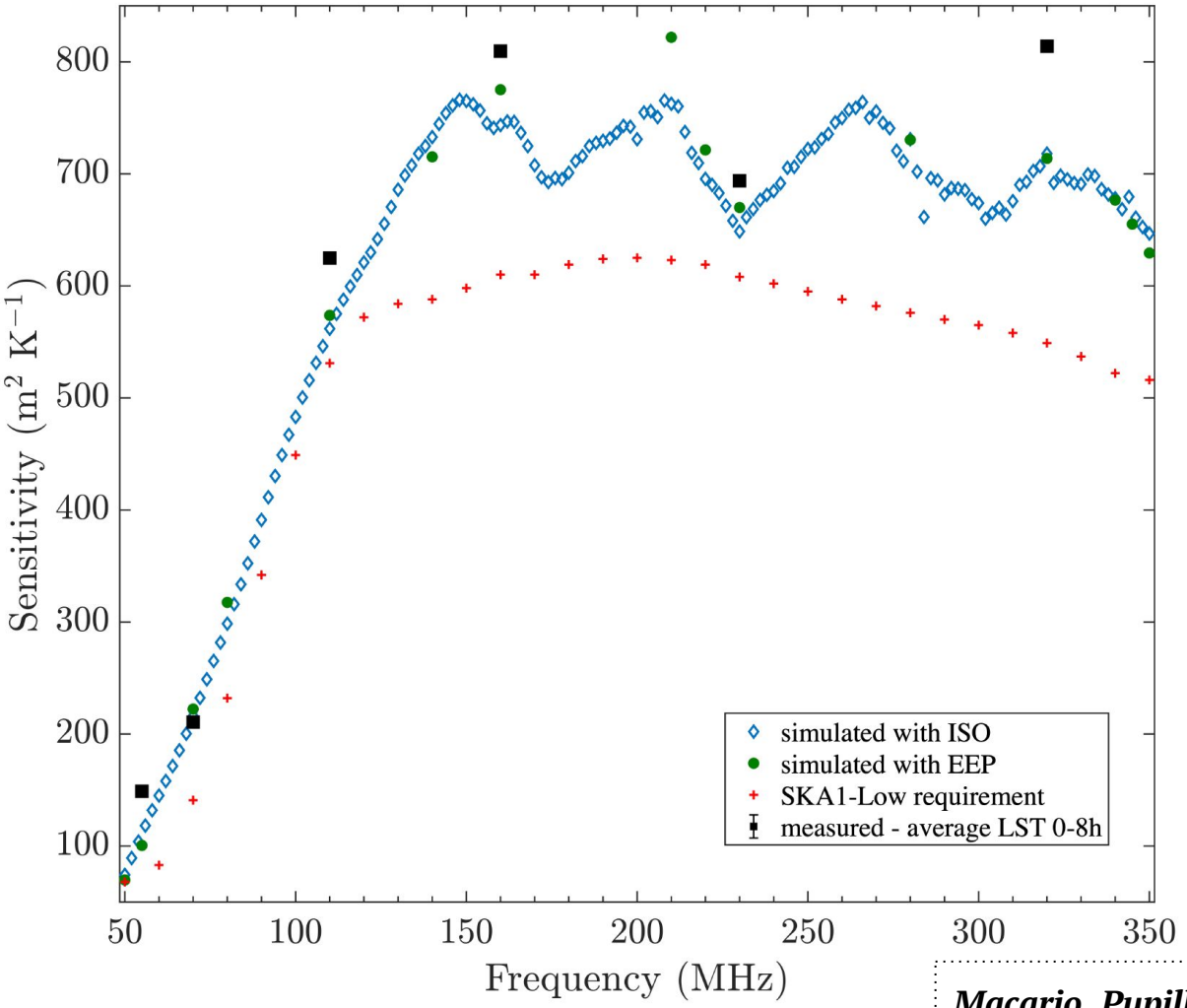
1) small variations 1h across transit (5-20%)
2) consistency with reference values



3) measured spectra follow reasonably well the expected power laws

Macario, Pupillo, Bernardi et al. 2021 *(Astro-ph)*

2. SKA1-Low zenith sensitivity

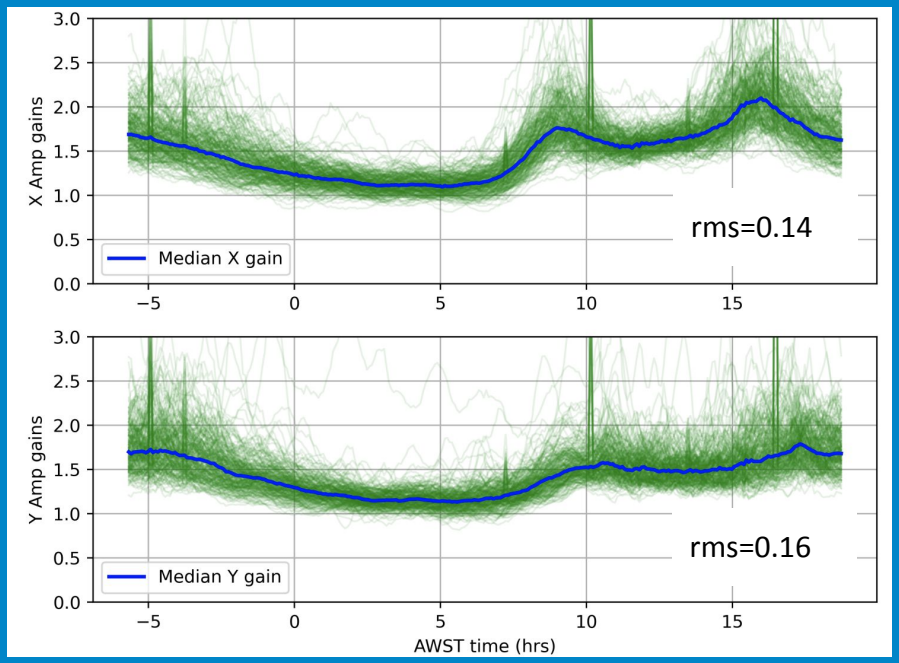


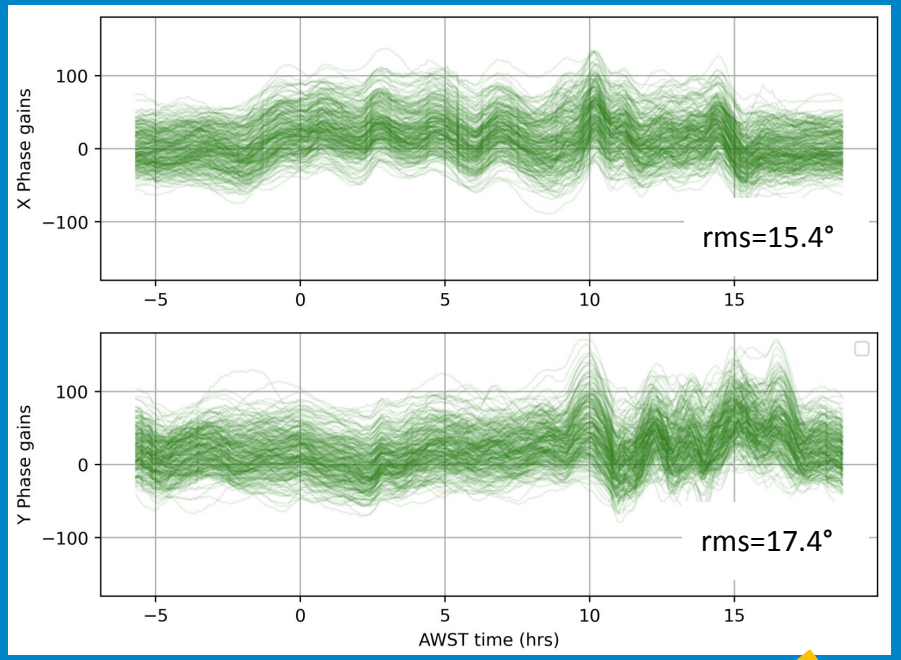
- averaged sensitivities (between the XX and YY pol. and in LST 0-8h)
- good agreement with simulation, (≲13%)
- meet SKA1-Low requirements at all frequencies (up to ~2.3 above) - LST averaging dependent

Macario, Pupillo, Bernardi et al. 2021 *(Astro-ph)*

3. Calibration solutions stability

AAVS2 110 MHz - Global Sky Model + Sun calibration solutions



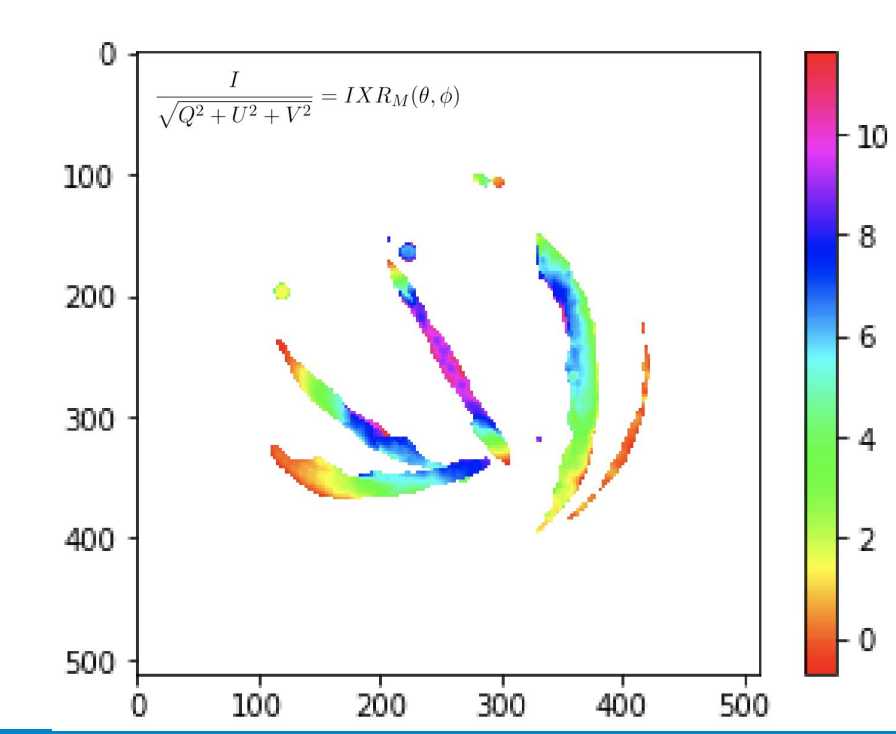


Credits: Ravi Subrahmanyan (RRI)

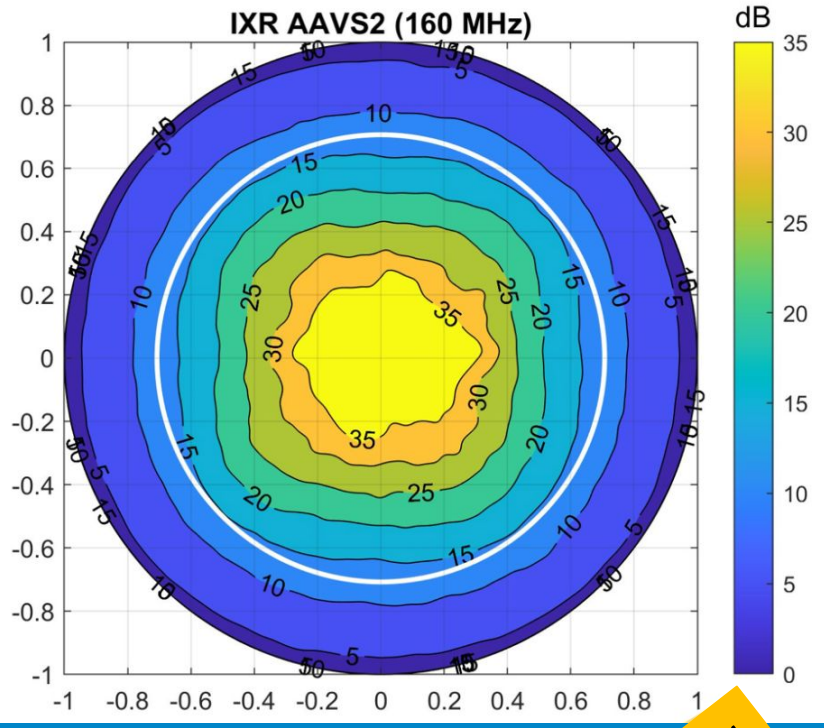
Work in progress!

3. Polarization performances

160 MHz IXR map (observed)



160 MHz IXR map (simulated)



more details in [this presentation]

Work in progress!

Conclusions and future work

- **AAVS2** is **calibratable** (at least to first order) **and** fairly **stable** (over at least 24 hours)
- estimated **SKA1-Low sensitivities agree with simulations** and **meet requirements**

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To be started / long term goals

- Extended RS flux densities analysis → ***report***
- Estimate of ionospheric effects through data/images → ***publication***
- Calibratability (especially at low frequencies): sky models and/or other RS in the field → ***publication***

Future plans (proposals)

- Science/astronomy with AAVS2, i.e.:
  - building an all-sky model
  - study of Galactic emission (GC/ GP/diffuse structures) at low resolution
- AAVS2 + MWA or EDA2 for higher resolution, science → feasibility in light of AA0.5 (6 stations)
- Evaluation of commissioning science feasible with AA0.5