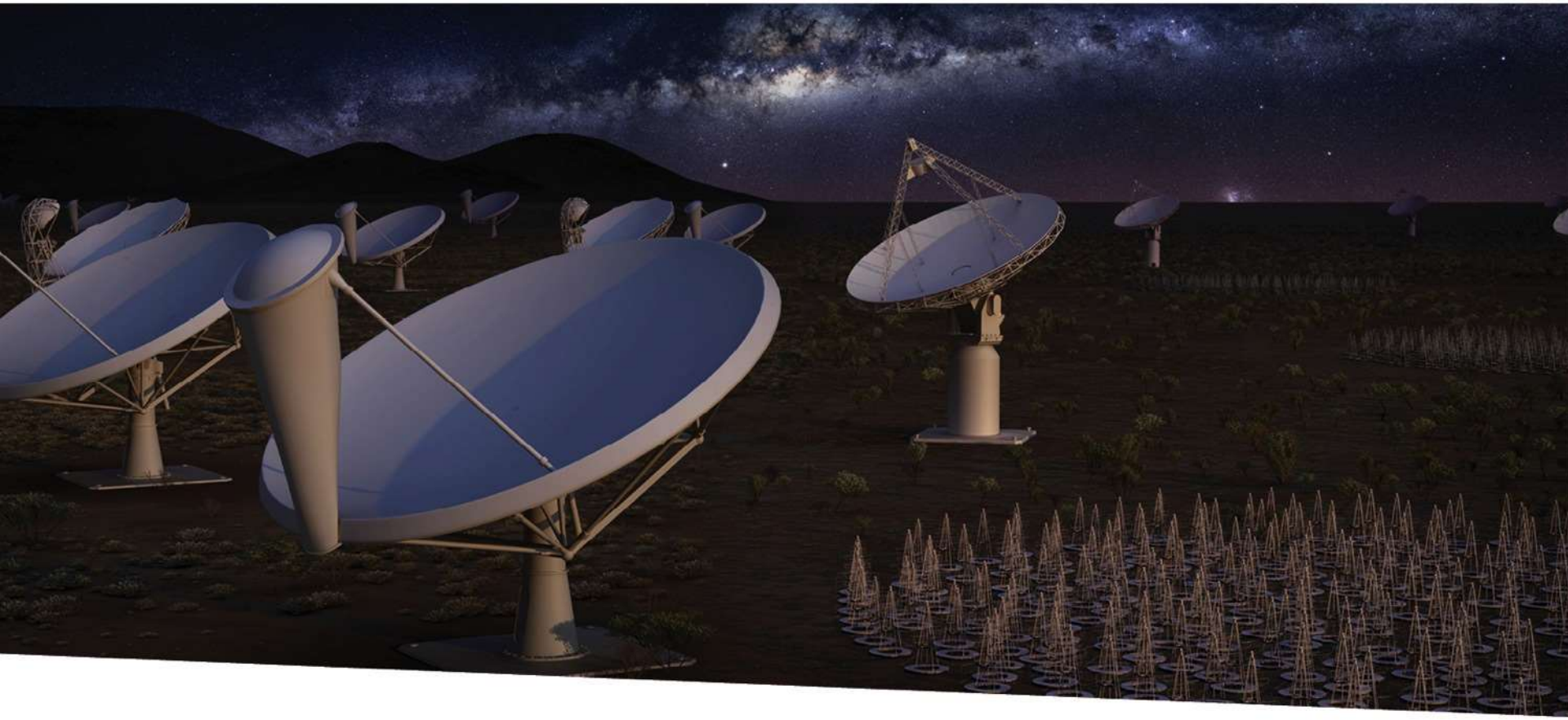
The SKA



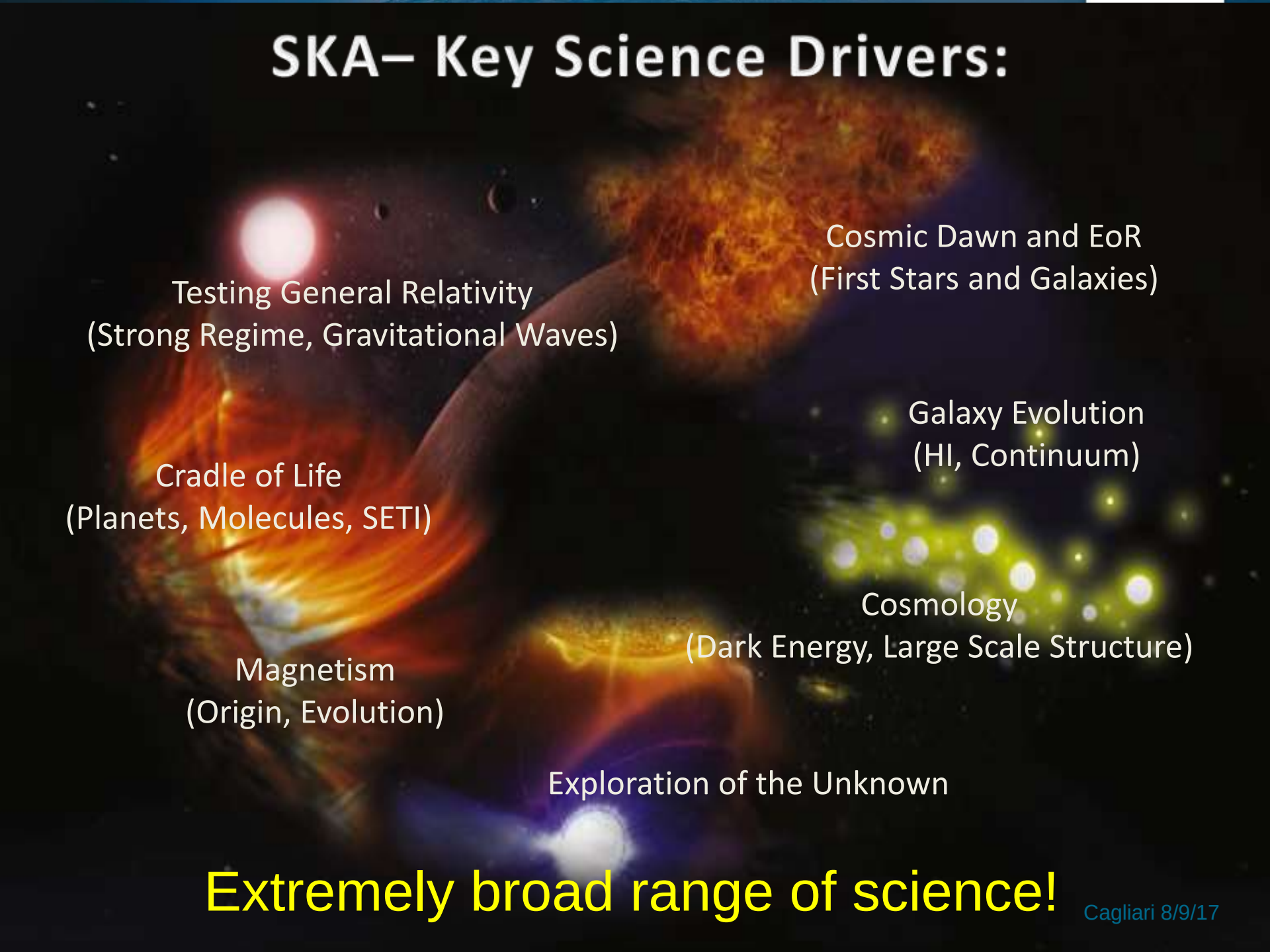
SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

Anna Bonaldi

SKA Project Scientist

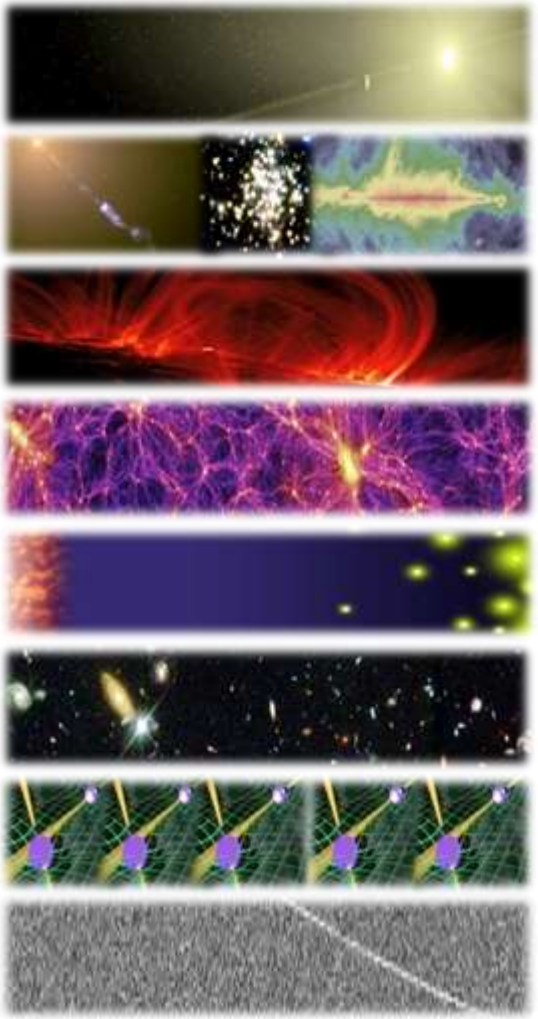
SKA– Key Science Drivers:



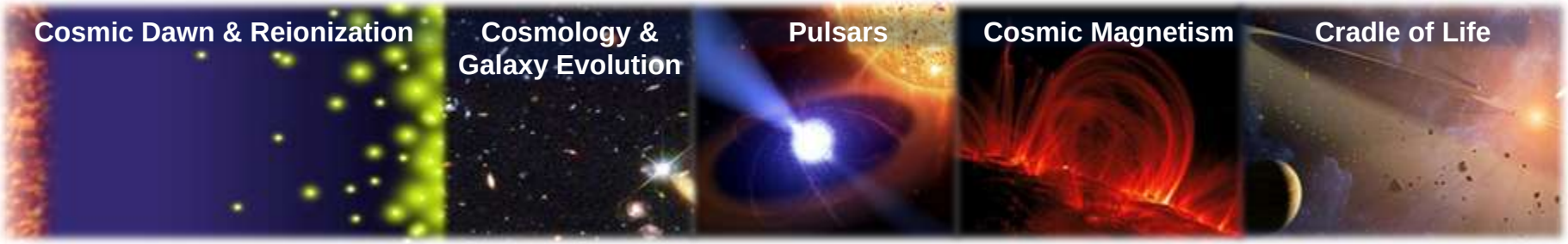
Extremely broad range of science!

SKA Big Questions

- **The Cradle of Life & Astrobiology**
  - *How do planets form? Are we alone?*
- **Strong-field Tests of Gravity with Pulsars and Black Holes**
  - *Was Einstein right with General Relativity?*
- **The Origin and Evolution of Cosmic Magnetism**
  - *What is the role of magnetism in galaxy evolution and the structure of the cosmic web?*
- **Galaxy Evolution probed by Neutral Hydrogen**
  - *How do normal galaxies form and grow?*
- **The Transient Radio Sky**
  - *What are Fast Radio Bursts? What haven't we discovered?*
- **Galaxy Evolution probed in the Radio Continuum**
  - *What is the star-formation history of normal galaxies?*
- **Cosmology & Dark Energy**
  - *What is dark matter? What is the large-scale structure of the Universe?*
- **Cosmic Dawn and the Epoch of Reionization**
  - *How and when did the first stars and galaxies form?*



SKA frequency coverage



50 MHz 100 MHz 1 GHz 10 GHz





SKA Low
50-350 MHz

SKA Mid Band 1
0.35-1.05 GHz

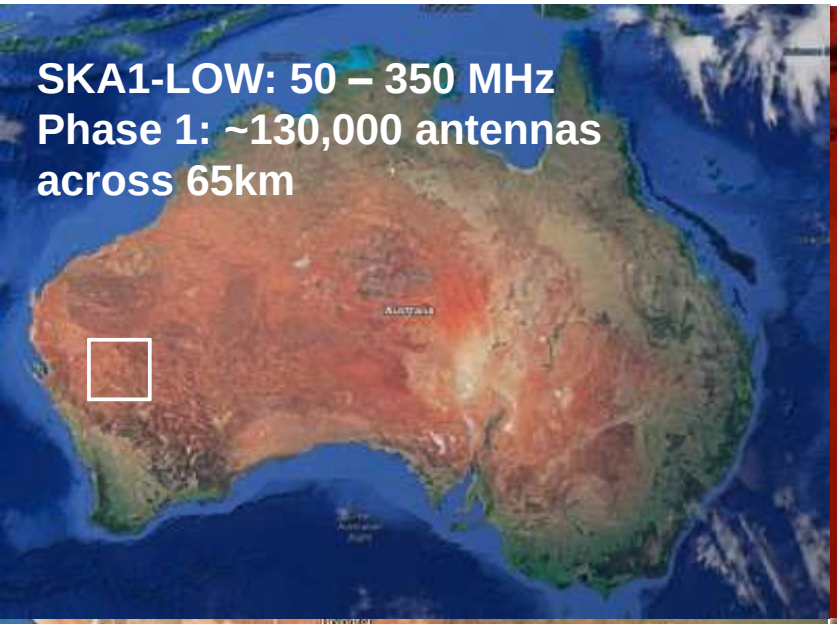
Band 2
0.95-1.76

Band 3
1.65-3.05

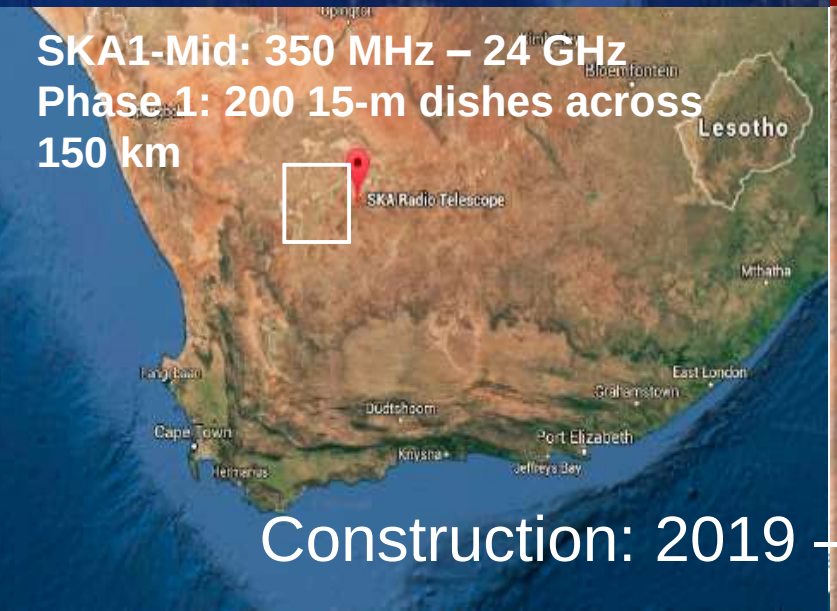
Band 4
2.80-5.18

Band 5
4.6-24 GHz

SKA: HQ in UK; telescopes in AUS & RSA









Construction: 2019 – 2024; Cost cap: €674M

Two phases of deployment

Phase I



~131,000 element Low Frequency Aperture Array

Band 1, Band 2, Band 5a+b only
0.35-1.76 GHz + 4.6-15.3 GHz

2020



~200 dishes

Phase II



~1,000,000 element Low Frequency Aperture Array



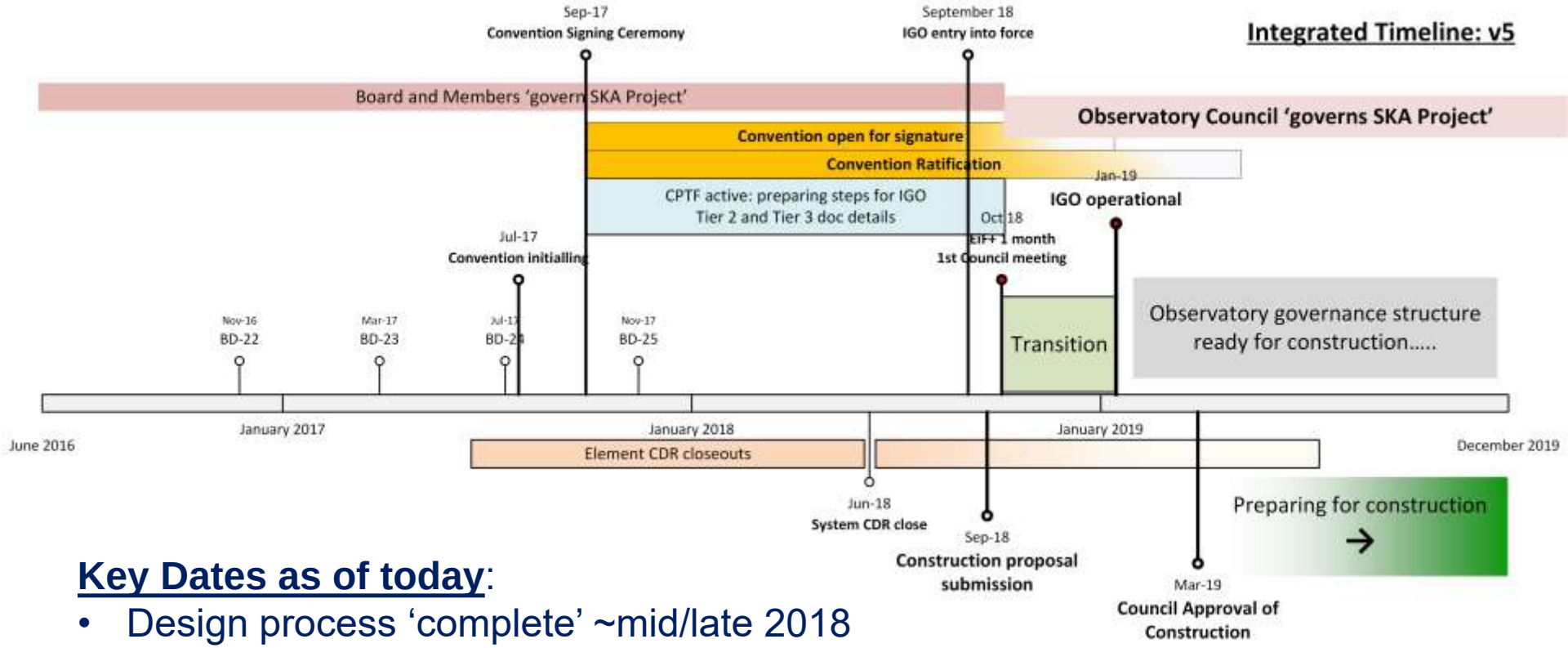
Mid Frequency Aperture Array / Phased Array Feeds

2025+



~2500 dishes

The overall project schedule…..



Key Dates as of today:

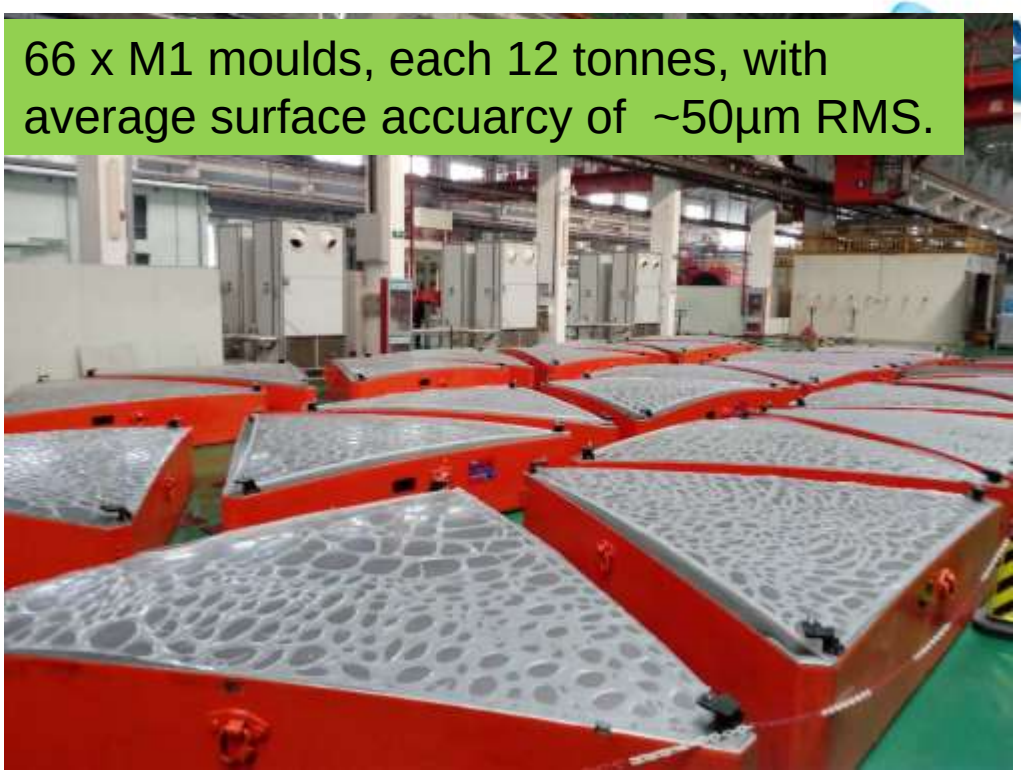
- Design process 'complete' ~mid/late 2018
- IGO in operation: early 2019
- IGO Council approves construction: early/mid 2019
- SKA1 construction procurement begins: ~late 2019

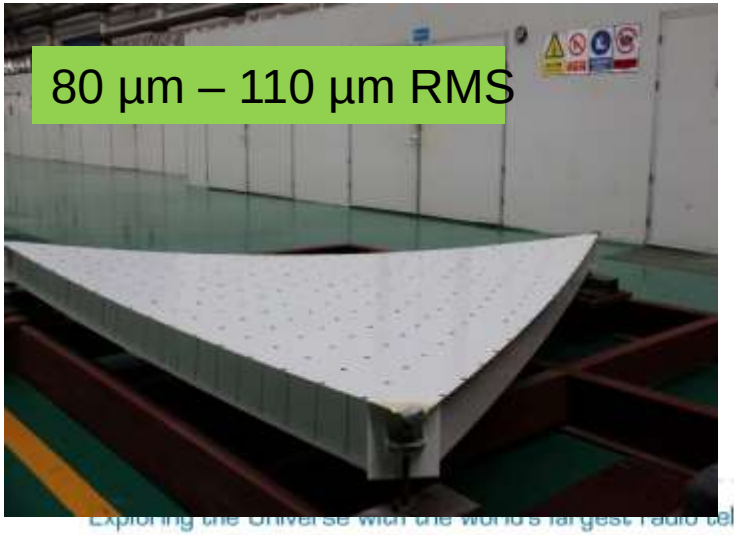
- **Commissioning/Early science from 2021**
- **Full operations from 2025**

Technical Progress



66 x M1 moulds, each 12 tonnes, with average surface accuarcy of ~50µm RMS.







Technical progress

Dish foundation



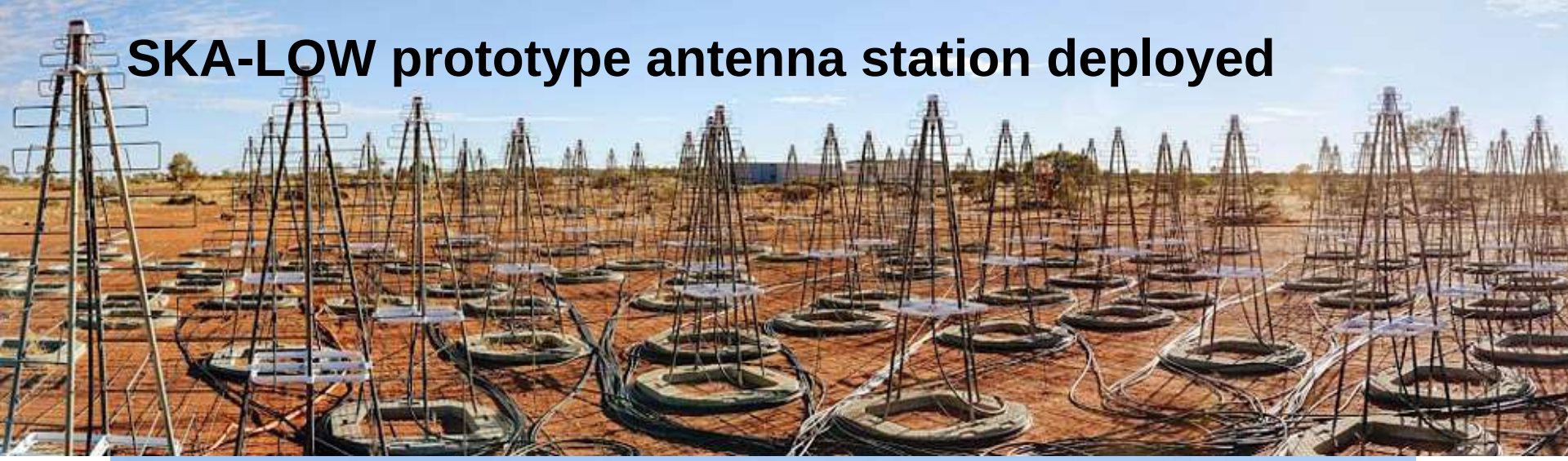
Feed indexer from SAM, Italy





- SKA-P Prototype
  Assembly starts in China 09/2017
- SKA-MPI Prototype
  Assembly starts in South Africa end of 2017

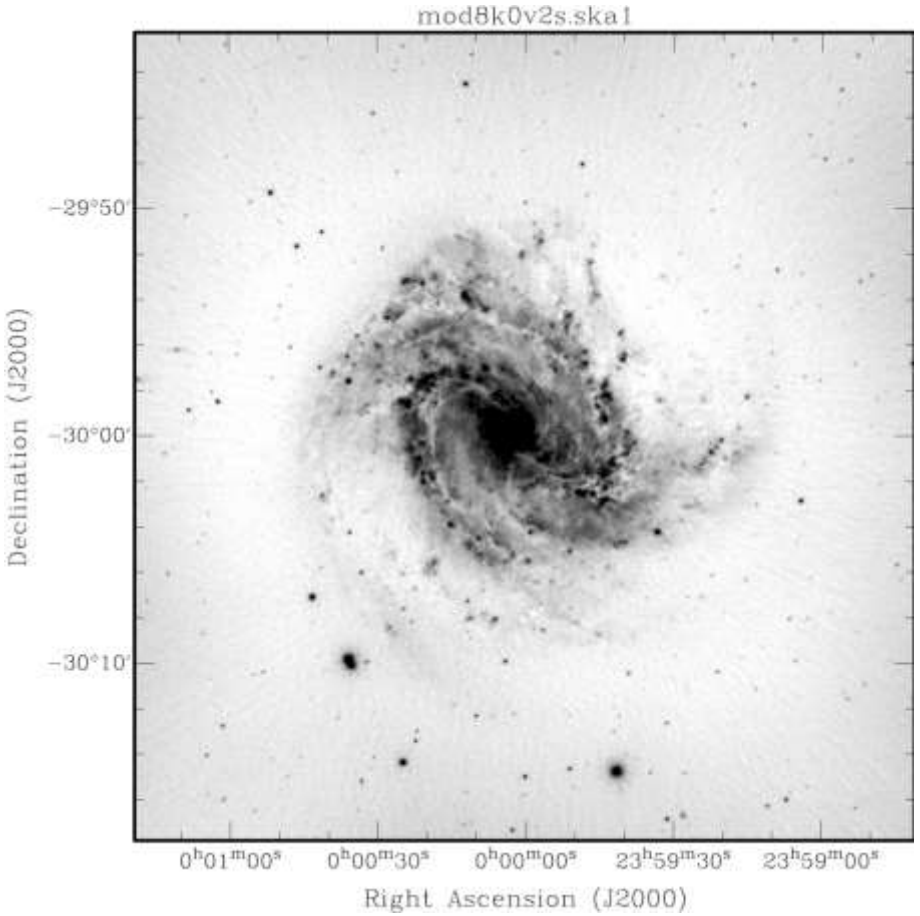
SKA-LOW prototype antenna station deployed

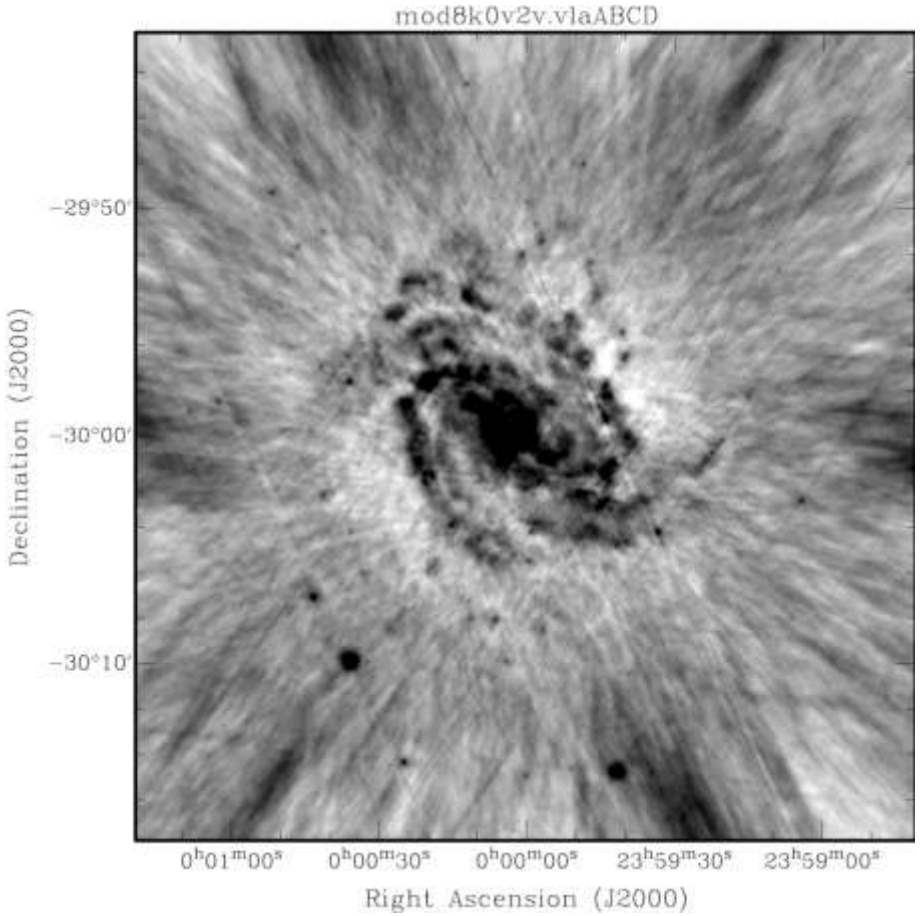


2.6 MWhr lithium ion battery



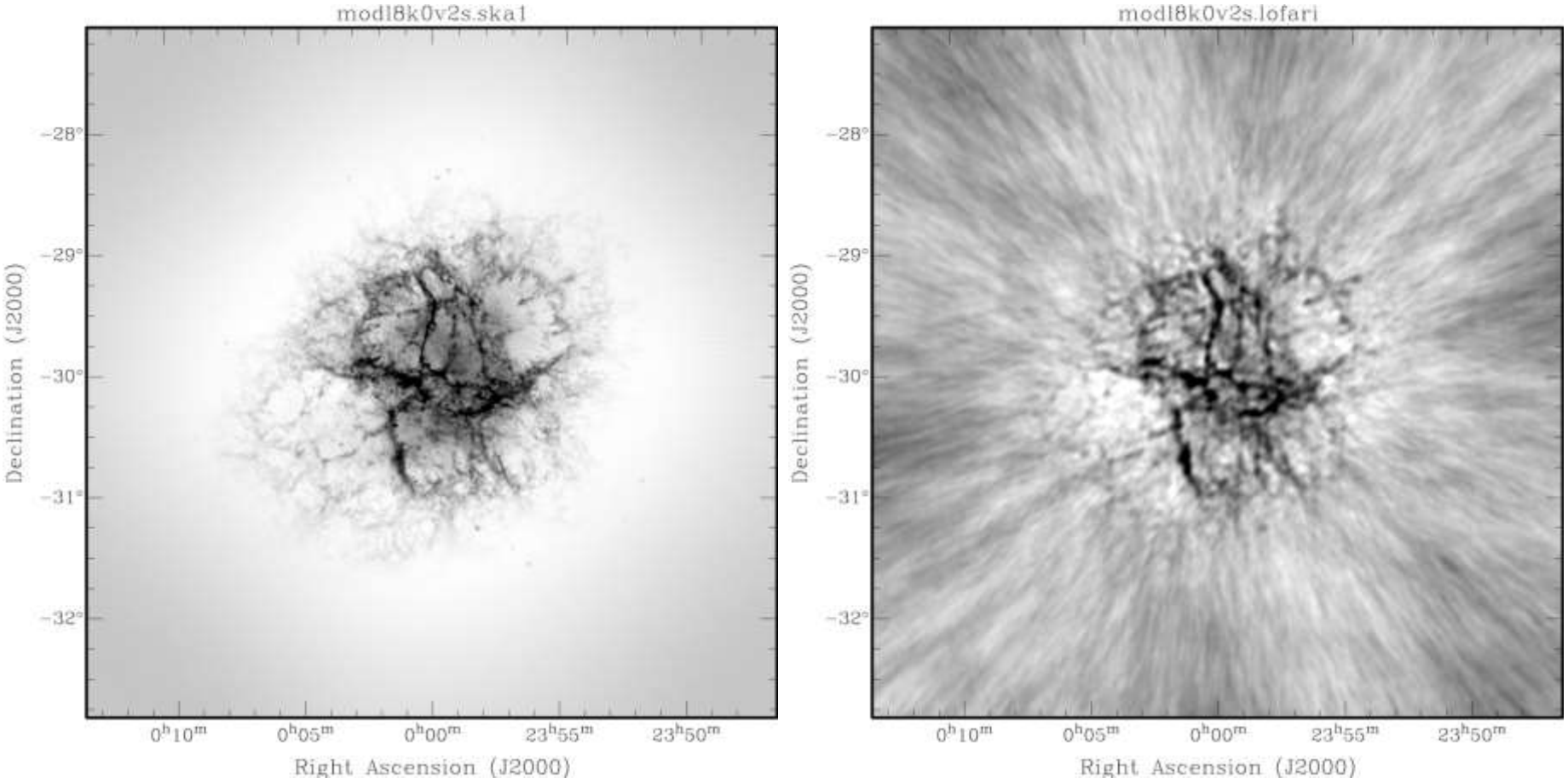
Image Quality Comparison





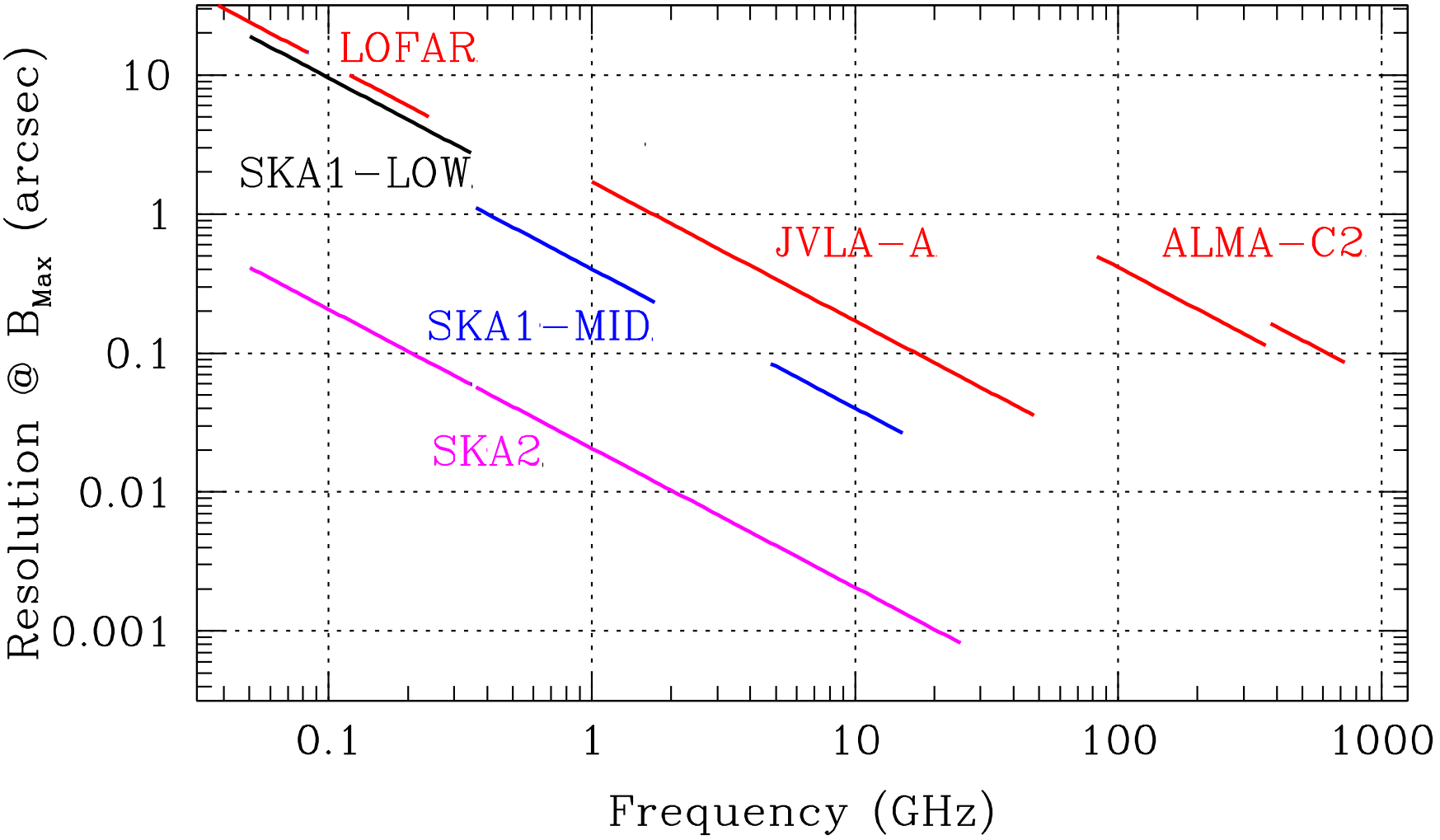
- Single SKA1-Mid snap-shot compared to combination of snap-shots in each of VLA A+B+C+D

Image Quality Comparison

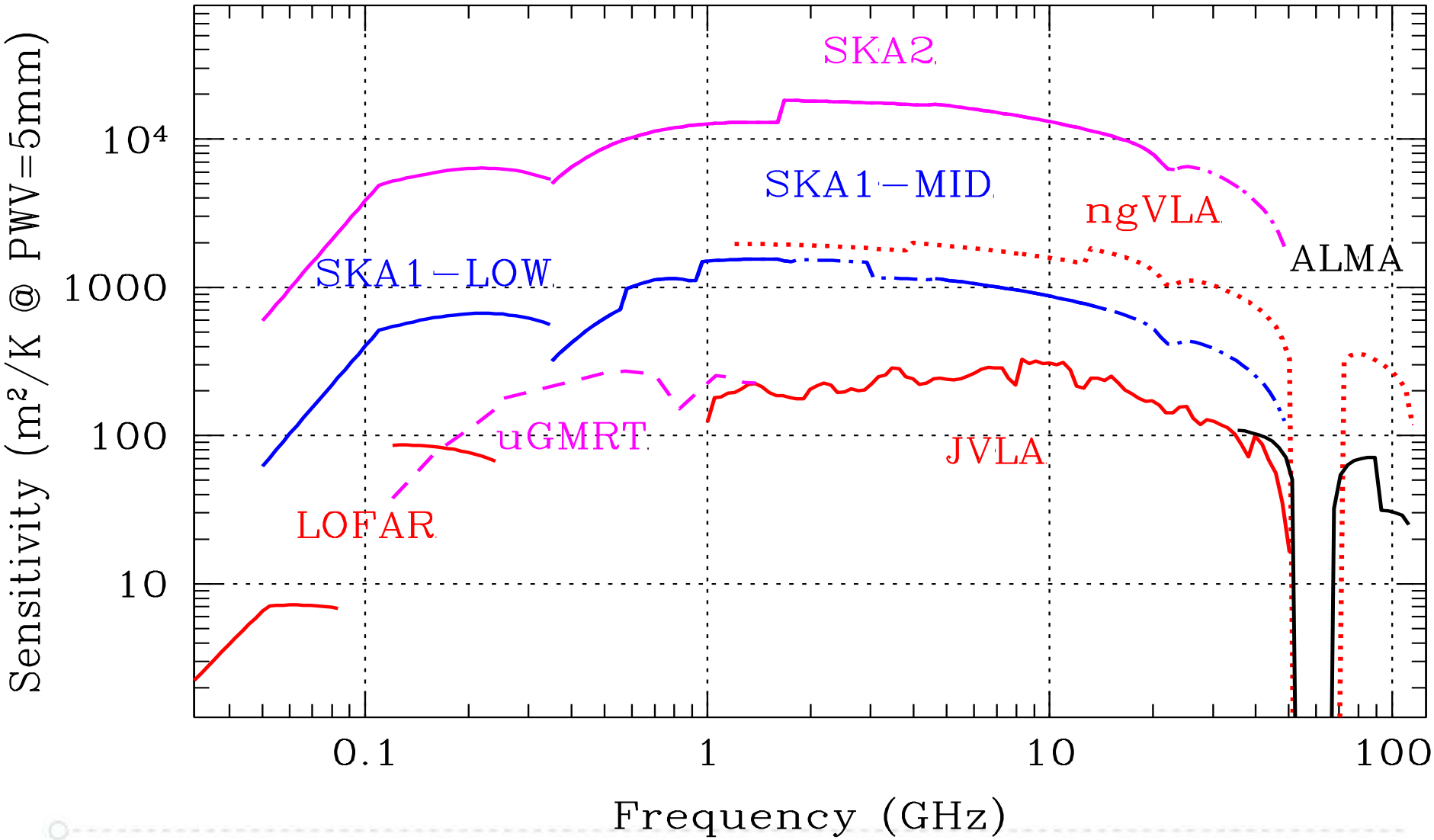


- Single SKA1-Low snap-shot compared to LOFAR-INTL snap-shot

Resolution Comparison



Sensitivity Comparison



Bands

SKA1

Band	Frequency Range	Bandwidth
Low	50 – 350 MHz	300 MHz
Mid Band 1	0.35 – 1.05 GHz	1 GHz
Mid Band 2	0.95 – 1.76 GHz	1 GHz
Mid Band 5a	4.6 – 8.5 GHz	2 x 2.5 GHz
Mid Band 5b	8.3 – 15.3 GHz	2 x 2.5 GHz

Upgrade paths

* To be confirmed

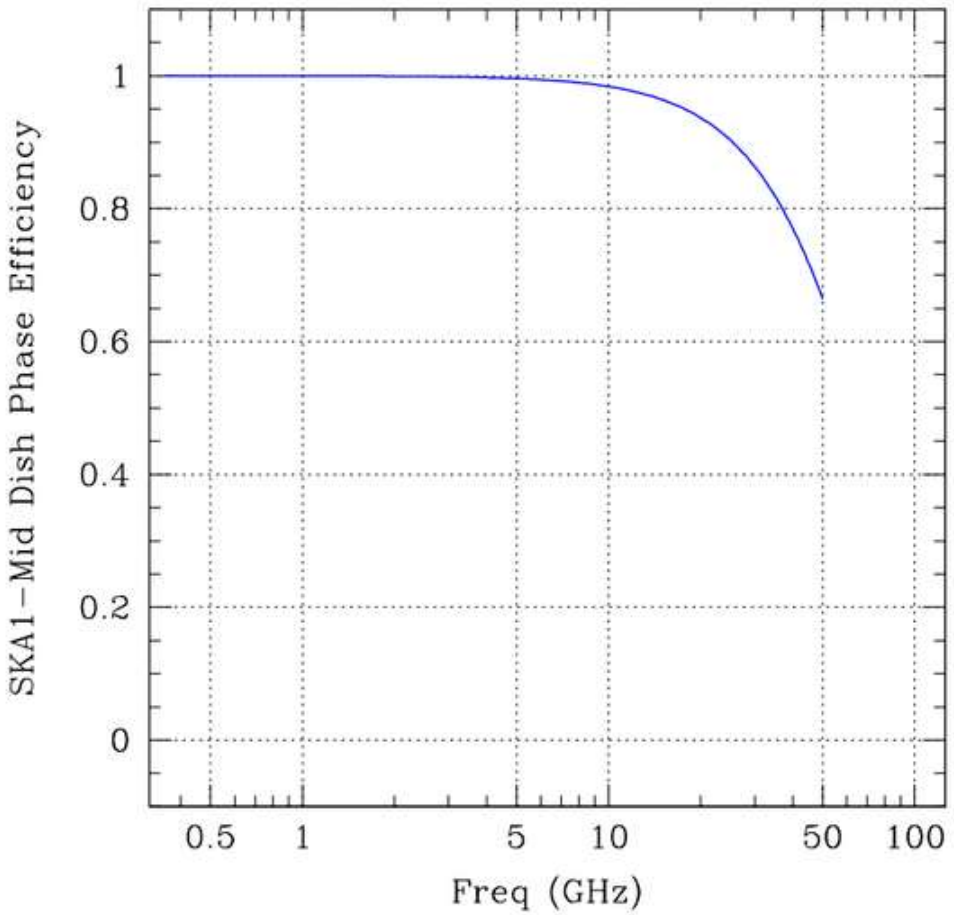
Mid Band A	1.6 – 5.2 GHz*	2.5 GHz
Mid Band B	4.6 – 24 GHz*	2 x 2.5 GHz*
Mid Band 5c	15 – 24 GHz*	2 x 2.5 GHz*

SKA2

Mid Band 3	1.65 – 3.05 GHz	1 GHz
Mid Band 4	2.80 – 5.18 GHz	2.5 GHz

High freq. performance

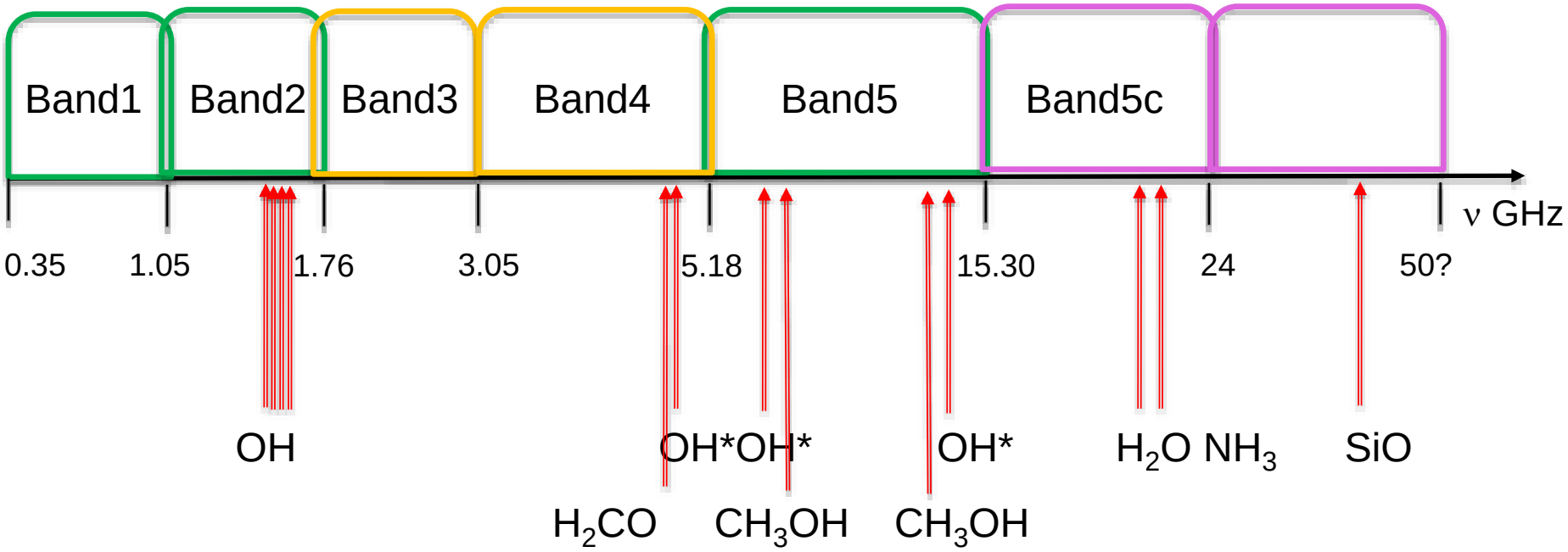




- Total surface RMS < 350 μm, relative pointing RMS <1.3 arcsec
- Good performance anticipated to **50 GHz**

Masers on SKA bands

SKA1 **SKA1->SKA2** **Possible upgrades**



Spectral resolution (Mid)

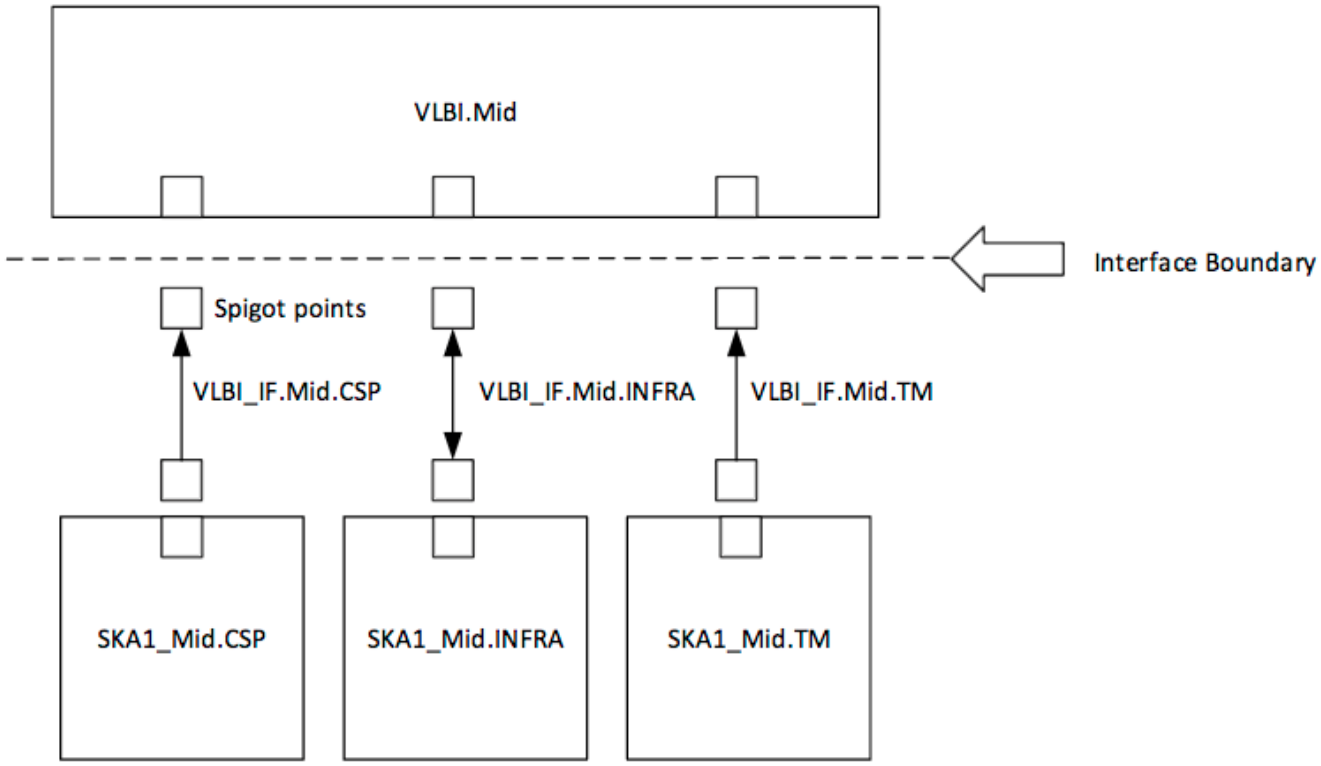
65,536 channels maximum across any band

"zoom windows" possible

SKA1 Mid zoom windows capabilities:

Window [MHz]	1 channel [KHz]
200	12.5
100	6.25
50	3.12
25	1.56
12.5	0.78
6.25	0.38
3.125	0.19

VLBI capabilities



- VLBI capabilities for both Mid and Low
- High data rate recording and/or eVLBI interface to stream in real time
- Using all antennas/stations or subsets (subarrays)
- Flexible freq. resolution setup

SKA proposals

- Two kind of calls for proposal:
  - **PI proposals**: to be completed within one observing cycle
  - **Key science projects**: requiring significant more telescope time, run over multiple observing cycles
- Around 70% of the time in the first 5 years for key science projects
- Time allocation on scientific merit and country of PIs and CoIs (SKA member or not)
- Possibility of **“commensal” observations**

SKA Science Working groups

- Cosmology
- Cradle of life
- Extragalactic Continuum
- Extragalactic spectral line
- Epoch of Reionization
- Our Galaxy
- Pulsars
- Cosmic magnetism
- HI galaxy science
- Solar and heliospheric physics
- Transients

SKA Science Cases

http://indico.skatelescope.org/event/AdvancingAstrophysics2014

http://astronomers.skatelescope.org/documents/aaska14-presentations/

http://pos.sissa.it/cgi-bin/reader/conf.cgi?confid=215 (and ADS)

www.skatelescope.org/books/



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  - **Galactic-type masers in local Universe**
  - **Dense molecular gas traces (thermal and masers)**
  - **Wide-area line Maser rearches (OH/H_2O etc)**
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- **Our Galaxy**
  - **Masers astrometry with SKA and VLBI**
  - **OH masers in the Milky Way**
  - **Tiered (deep, wide and very wide) Galactic Plane surveys in Band5 and Band2**
- Pulsars
- Cosmic magnetism
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SKA Science Working groups

- Cosmology
- **Cradle of life**
  - **Mapping the dynamics of nearby clusters using maser emission**
- Extragalactic Continuum
- **Extragalactic spectral line**
- Epoch of Reionization
- **Our Galaxy**
- Pulsars
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SKA Science Working groups

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- **Extragalactic spectral line**
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- Transients

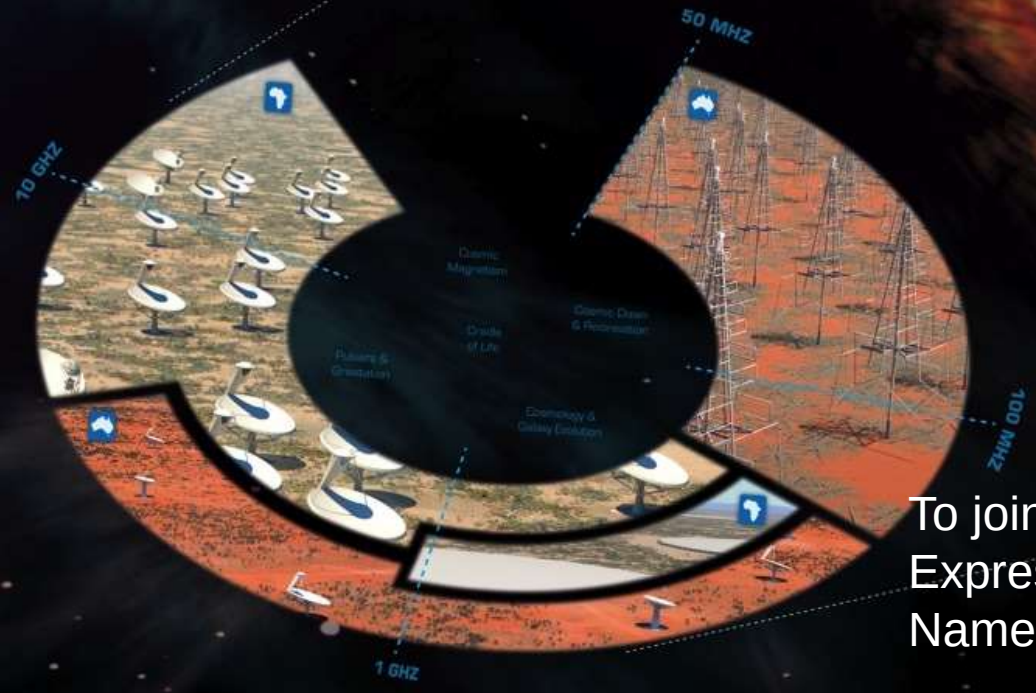
- **Mapping the dynamics of nearby clusters using maser emission**

- **Tiered (deep, wide and very wide) surveys in continuum and HI**
- **Catalogs of AGNs and SFGs for target selection**

SKA Science

The SKA will revolutionise our understanding of the Universe and the laws of fundamental physics

https://astronomers.skatelescope.org/



To join one of our science working group:
Express your interest to the SWG chairs
Names and contacts on the website!

Conclusions

- **SKA construction is on the horizon:**
  - Preliminary design review completed
  - Critical design review scheduled
  - Construction from mid 2019
  - Commissioning/Early science from 2021
  - Full operations from 2025
- **SKA will be great for doing masers science:**
  - Excellent sensitivity
  - Excellent imaging capabilities
  - Full polarization information
  - Good spectral resolution
  - VLBI capabilities
  - Wide blind surveys for finding new masers
  - You can join the SKA science community!

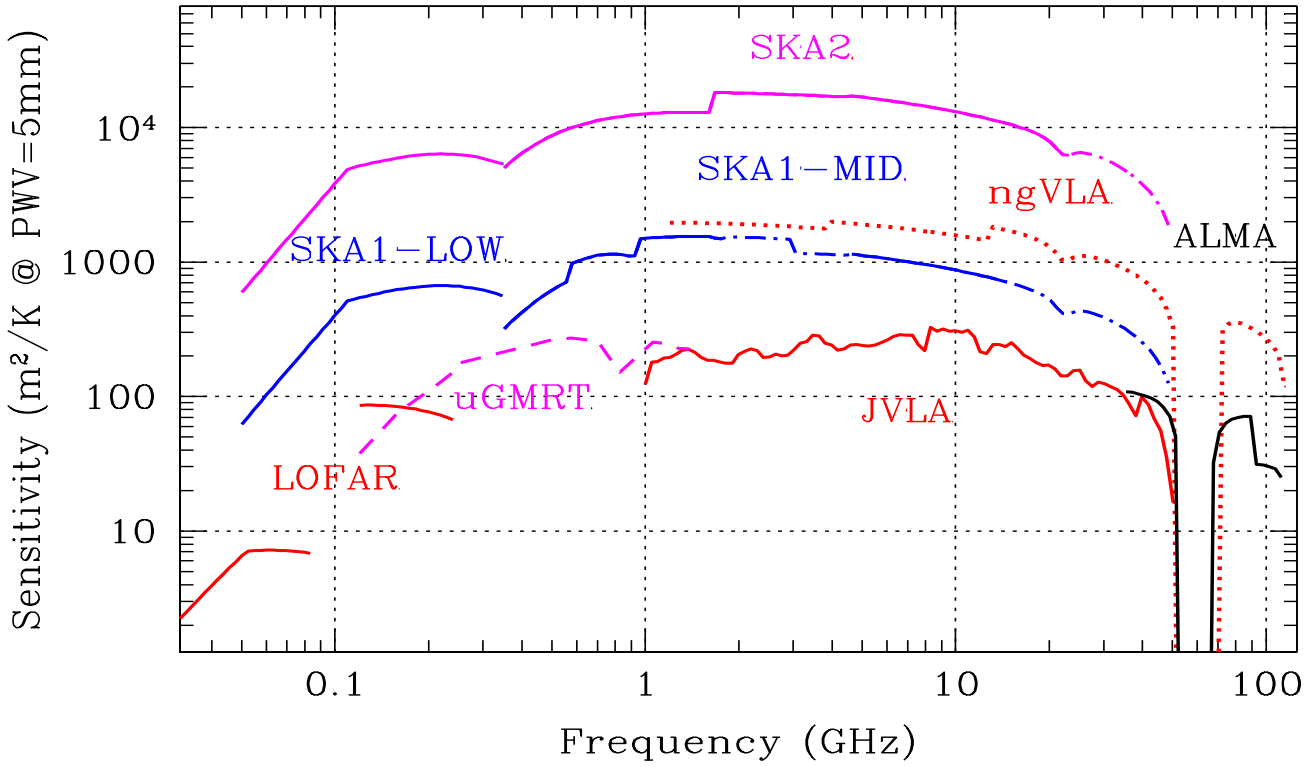
Deployment vs Design Baseline

Capped to 674 Meuro

Telescope	Feature	Design	Deployment
SKA1-Mid	No. dishes	133 (+64 Meerkat=197)	130 (+64 Meerkat=194)
	Max baseline	150 km	120 km
	Band 1 feeds	133	130
	Band 2 feeds	133	130
	Band 5 feeds	133	67
	Pulsar search	500 nodes	375 nodes
SKA1-Low	No. stations	512	476
	Max baseline	65 km	40 km
	Pulsar search	167 nodes	125 nodes
Common	Compute power	260 PFLOPS	50 PFLOPS

Baseline design implemented as soon as new funding is available

Sensitivity Comparison



Parametric model constrained by data

- SKA: test on prototypes and other documentation from the Dish consortium
- ngVLA: Gremmer, Sturgis and Butler, 2017, ngVLA Receiver/Feed Summary
- Weather: dry conditions (PWV=5 mm)