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LOFAR & SKA

Anna Scaife

with thanks to
Justin Bray

Interferometry Centre of Excellence
Jodrell Bank Centre for Astrophysics

erc

LOFAR
MAGNETISM
Key Science Project

SKA
SQUARE KILOMETRE ARRAY
SDP
SCIENCE DATA PROCESSOR

RAPP Inauguration, 22 September 2016

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The Low Frequency Array (LOFAR)

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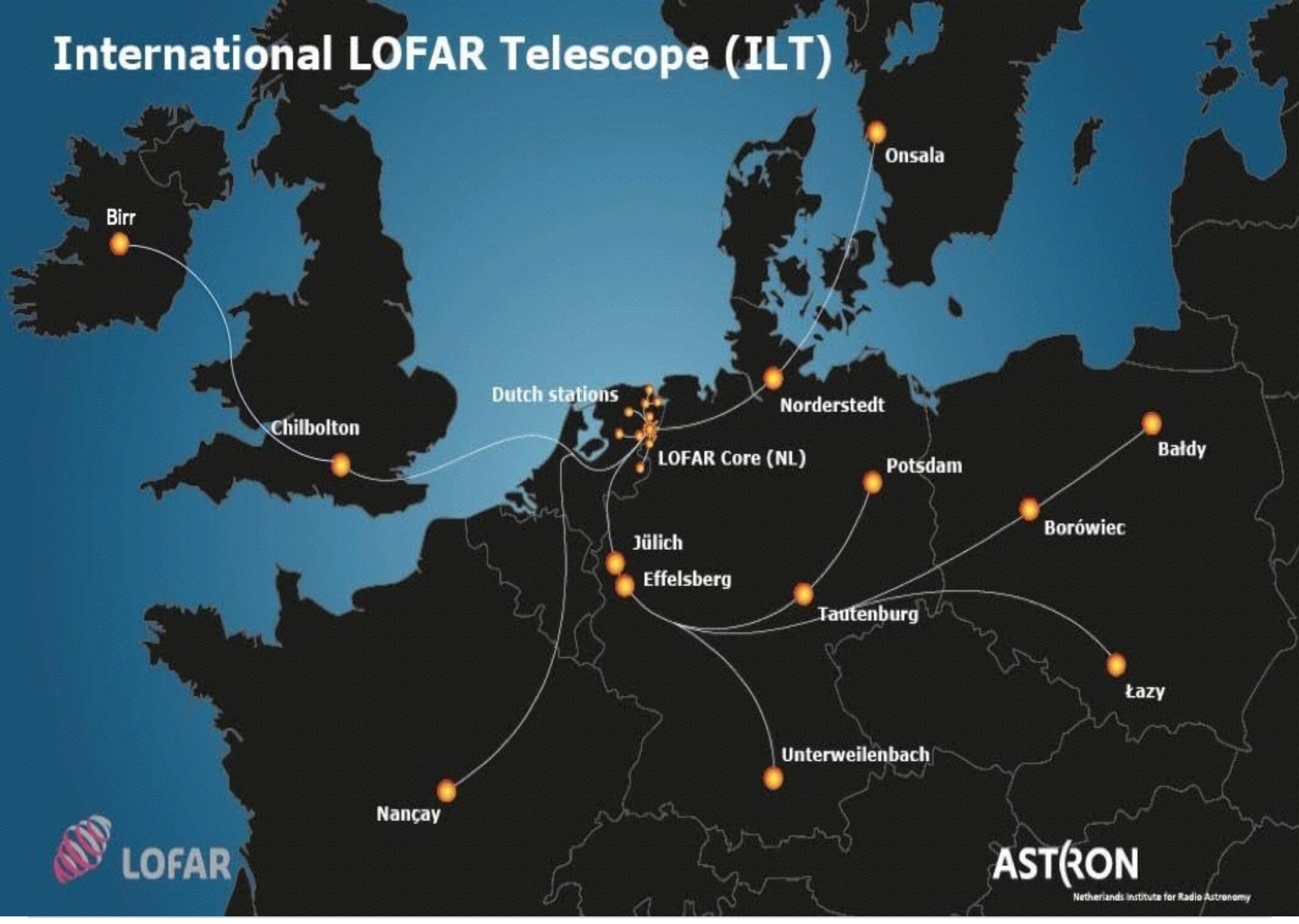
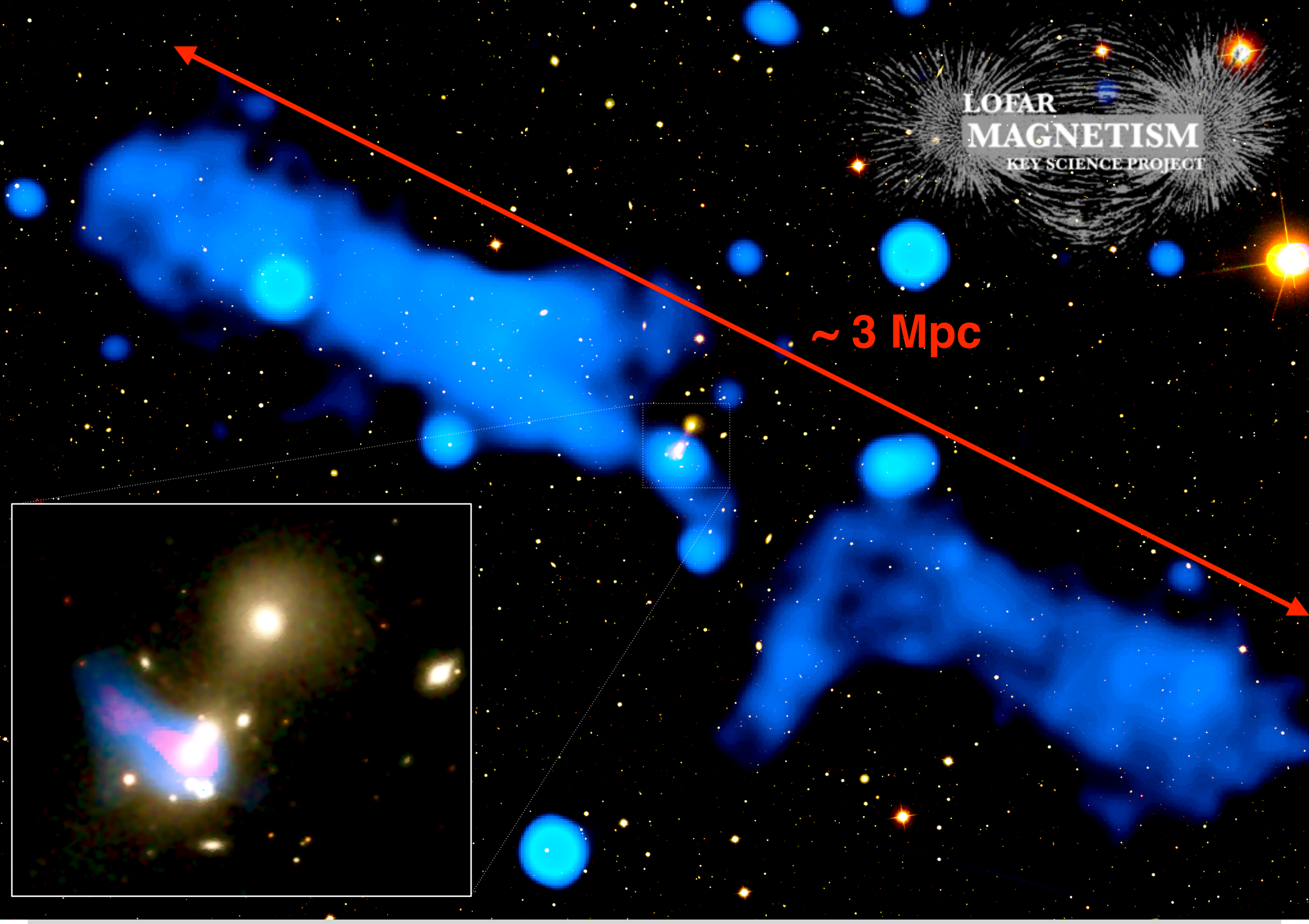
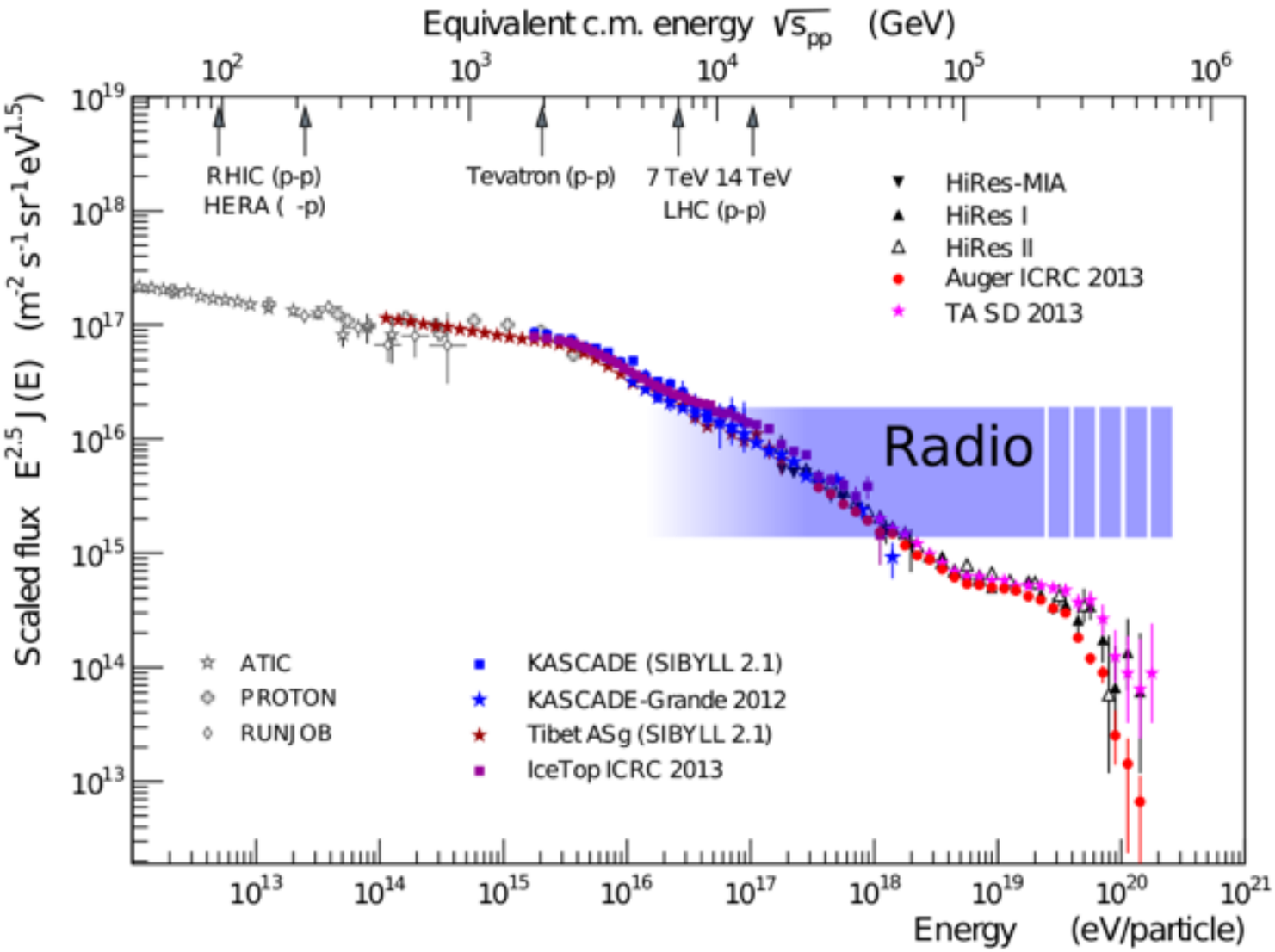
International LOFAR Telescope (ILT)





Clarke et al. 2016, in prep.

Cosmic Rays in the radio spectrum



- Radio can probe the cosmic-ray spectrum between the 'knee' (~10^{16} eV) and the 'ankle' (~10^{19} eV).
- Advantages:
  - ~100 % duty cycle
  - commensal observing
  - possibly better precision?

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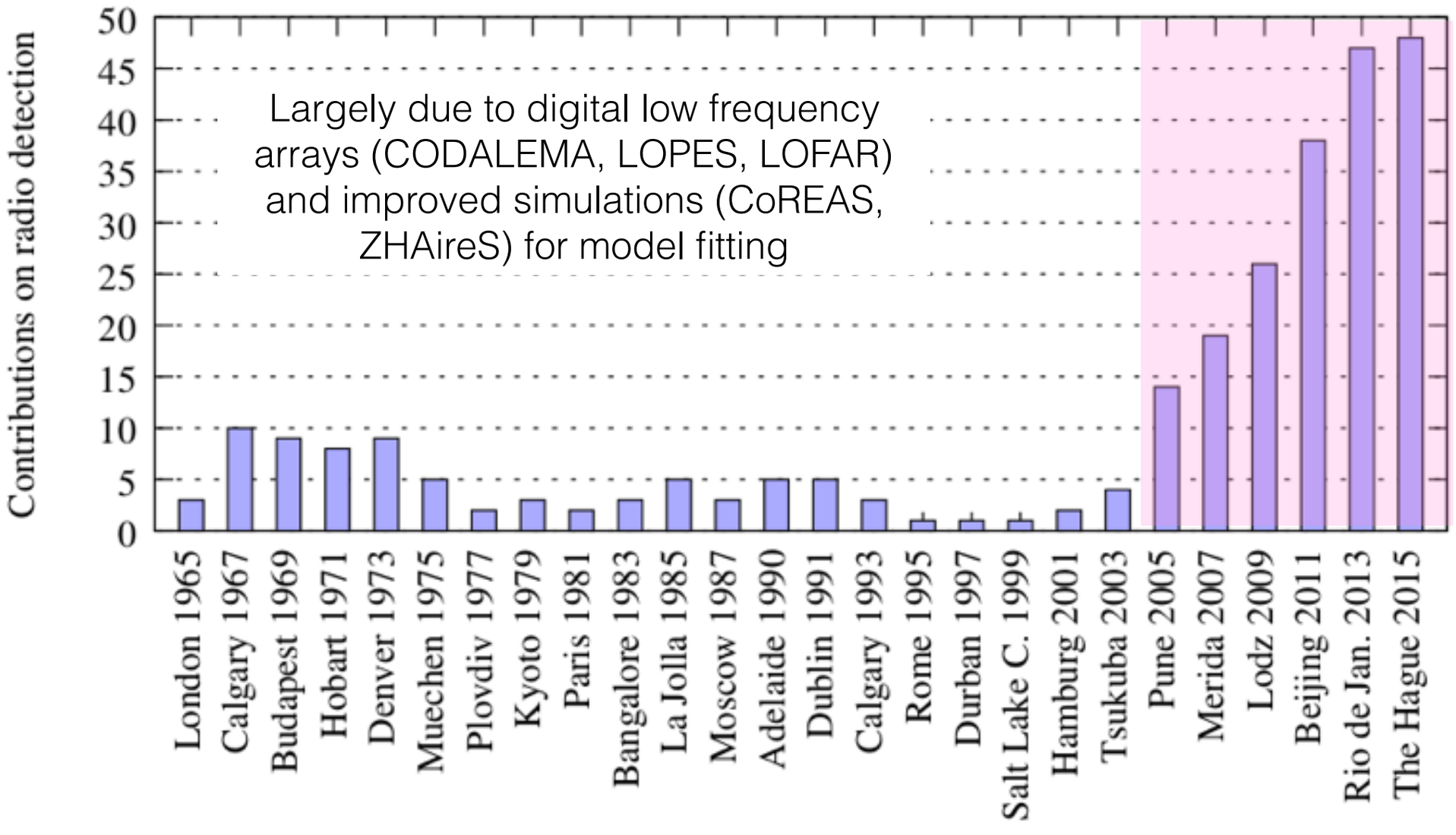
Radio Papers at ICRC
- the radio "renaissance"



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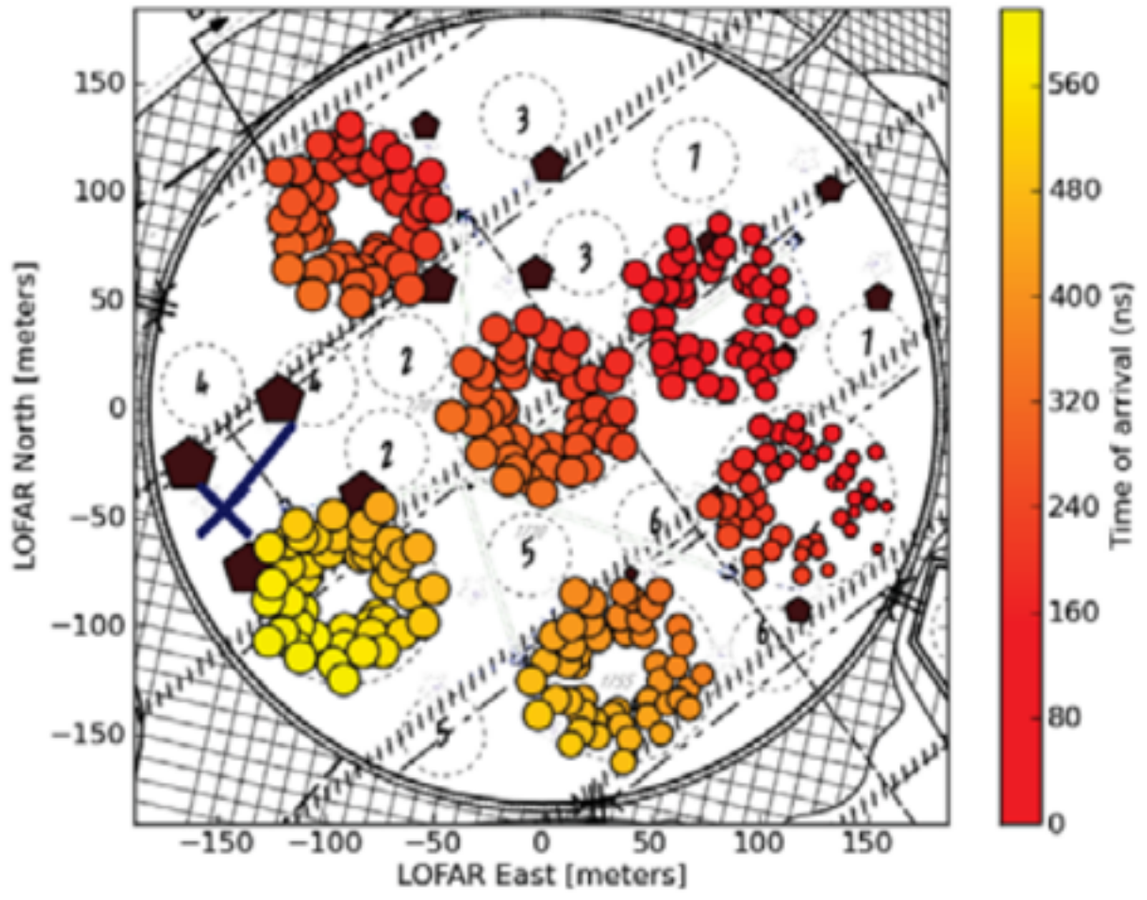
Cosmic Rays with LOFAR

- LOFAR Superterp provides dense sampling of air shower pulse
- Leads to high precision in power penetration depth and hence precise measurements of the original cosmic ray



Buitink et al. 2016, Nature

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The Square Kilometre Array (SKA)

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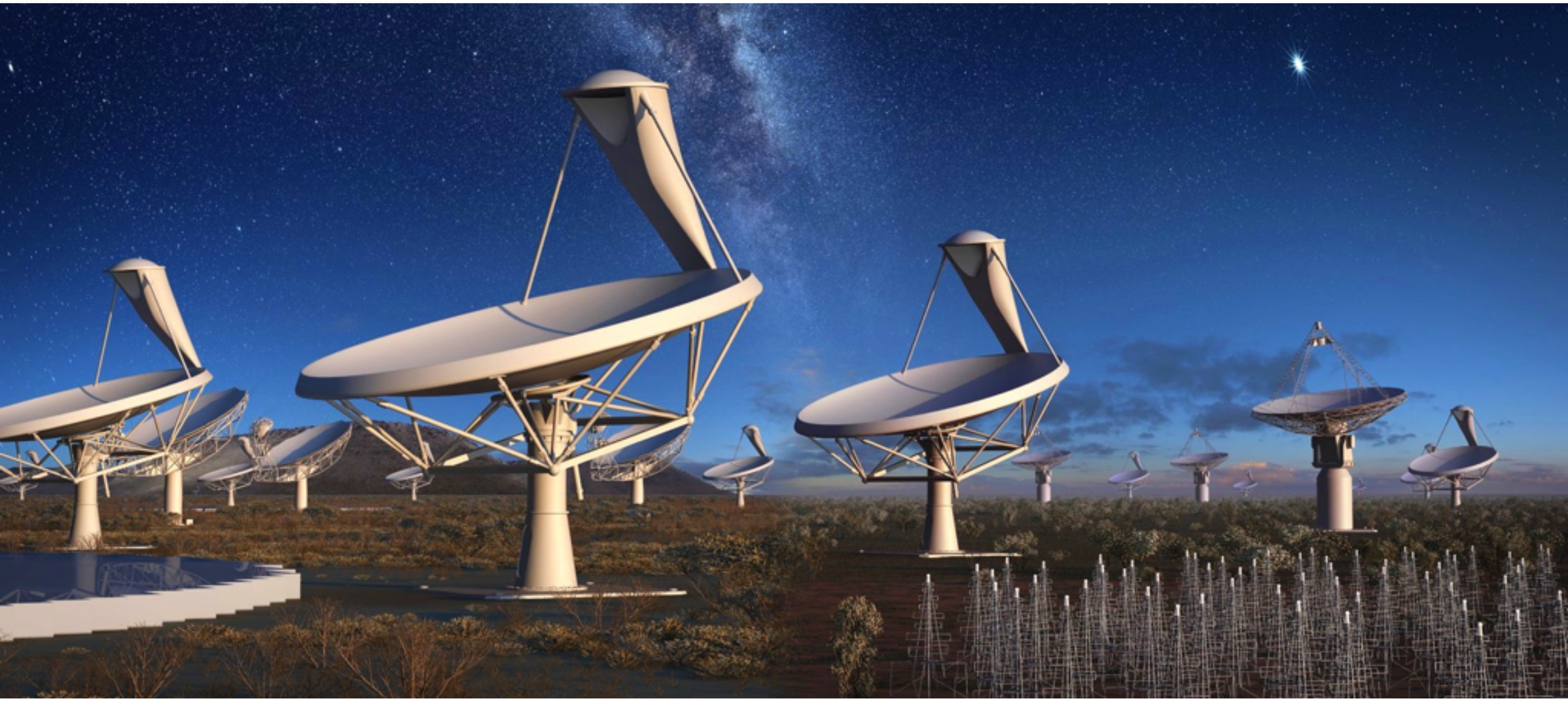
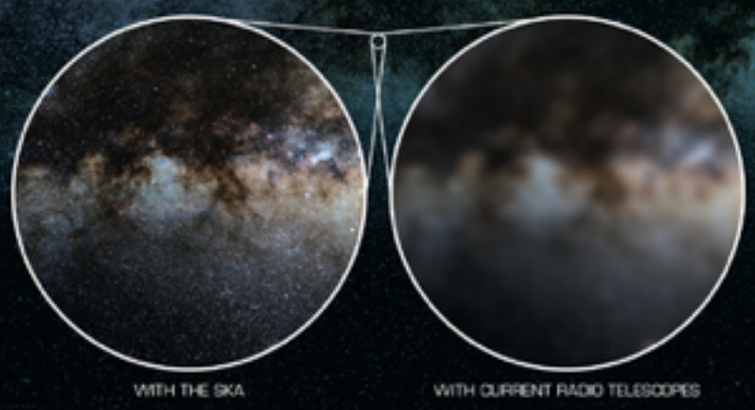


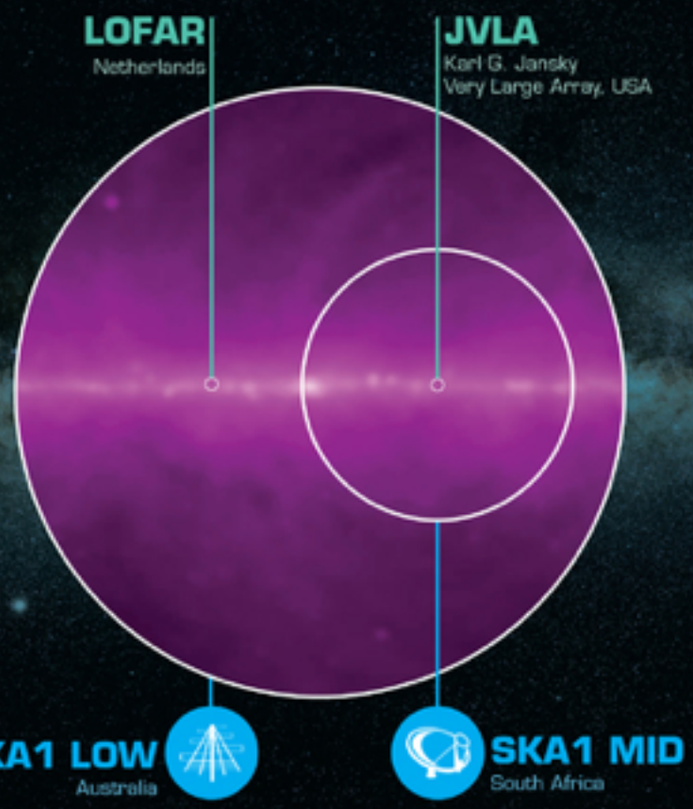
RAPP Inauguration, 22 September 2016

How will SKA1 be better than today's best radio telescopes?

Astronomers assess a telescope's performance by looking at three factors - **resolution**, **sensitivity**, and **survey speed**. With its sheer size and large number of antennas, the SKA will provide a giant leap in all three compared to existing radio telescopes, enabling it to revolutionise our understanding of the Universe.

The **Square Kilometre Array** (SKA) will be the world's largest radio telescope. It will be built in two phases - SKA1 and SKA2 - starting in 2018, with SKA1 representing a fraction of the full SKA. SKA1 will include two instruments - **SKA1 MID** and **SKA1 LOW** - observing the Universe at different frequencies.





SKA1 LOW x1.2 LOFAR NL

SKA1 MID x4 JVLA

RESOLUTION

Thanks to its size, the SKA will see smaller details, making radio images less blurry, like reading glasses help distinguish smaller letters.

SKA1 LOW x135 LOFAR NL

SKA1 MID x60 JVLA

SURVEY SPEED

Thanks to its sensitivity and ability to see a larger area of the sky at once, the SKA will be able to observe more of the sky in a given time and so map the sky faster.

SKA1 LOW x8 LOFAR NL

SKA1 MID x5 JVLA

SENSITIVITY

Thanks to its many antennas, the SKA will see fainter details, like a long-exposure photograph at night reveals details the eye can't see.

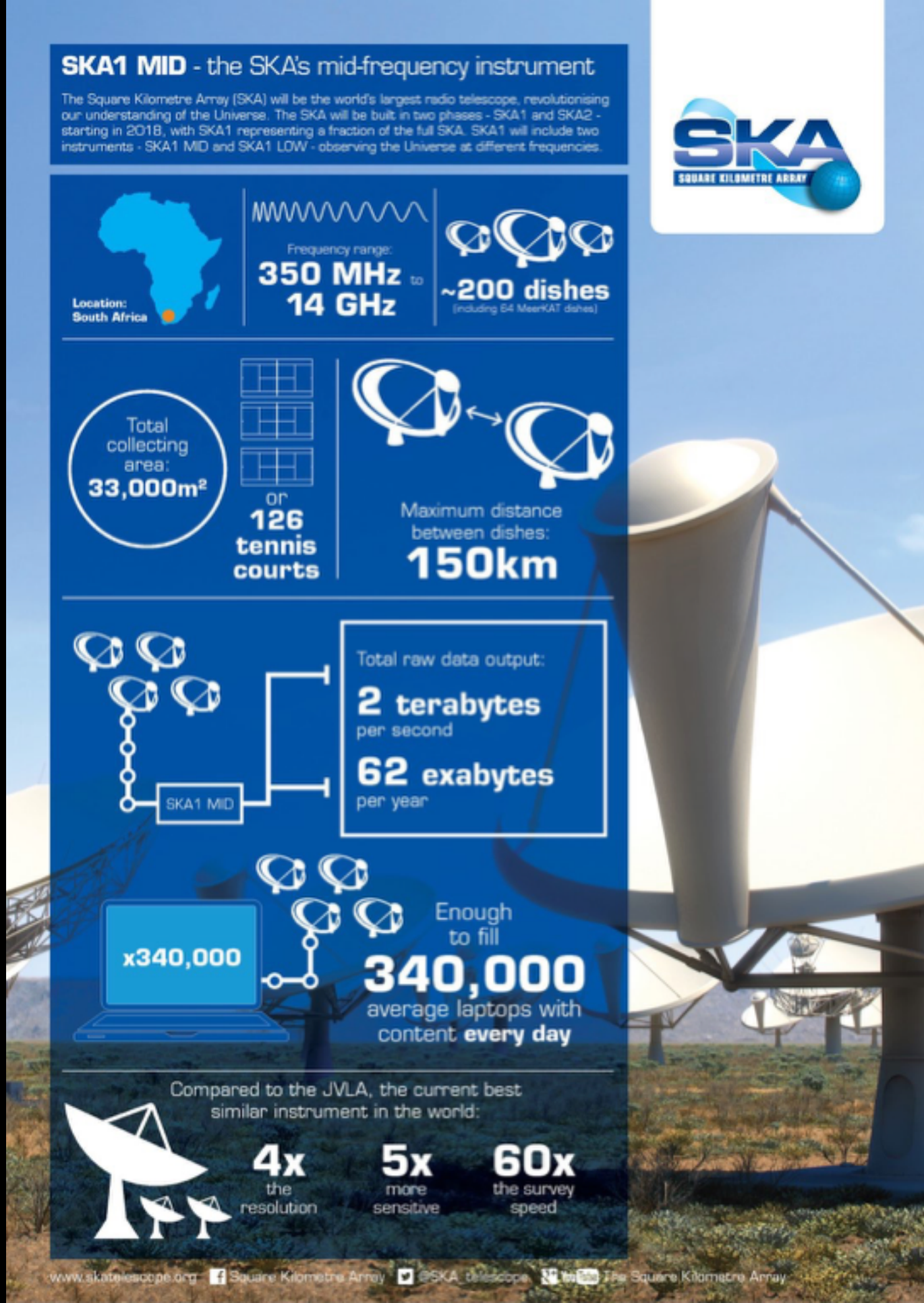
As the SKA isn't operational yet, we use an optical image of the Milky Way to illustrate the concepts of increased sensitivity and resolution.

SKA MID

DISH ARRAY

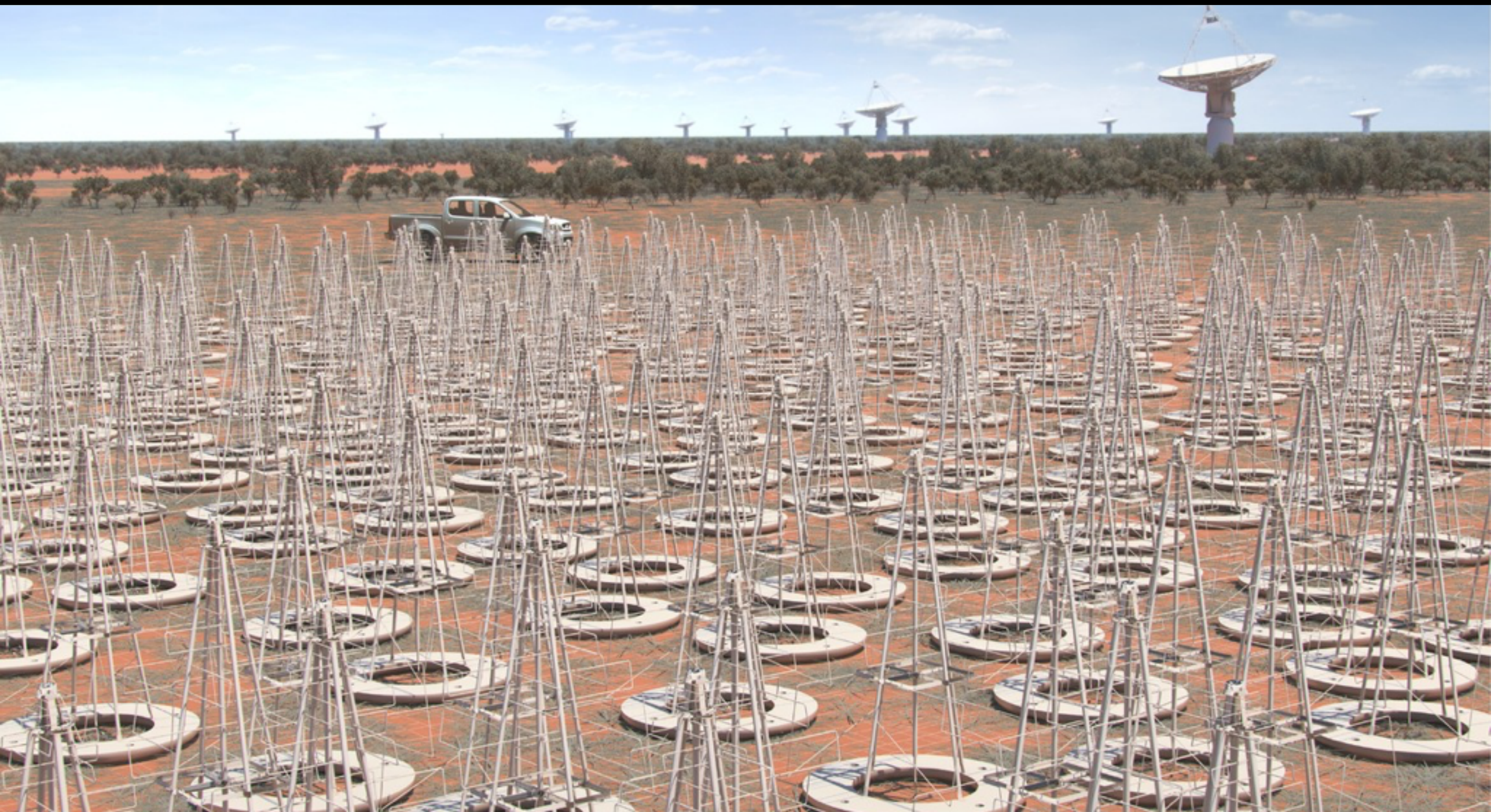
DISH ARRAY

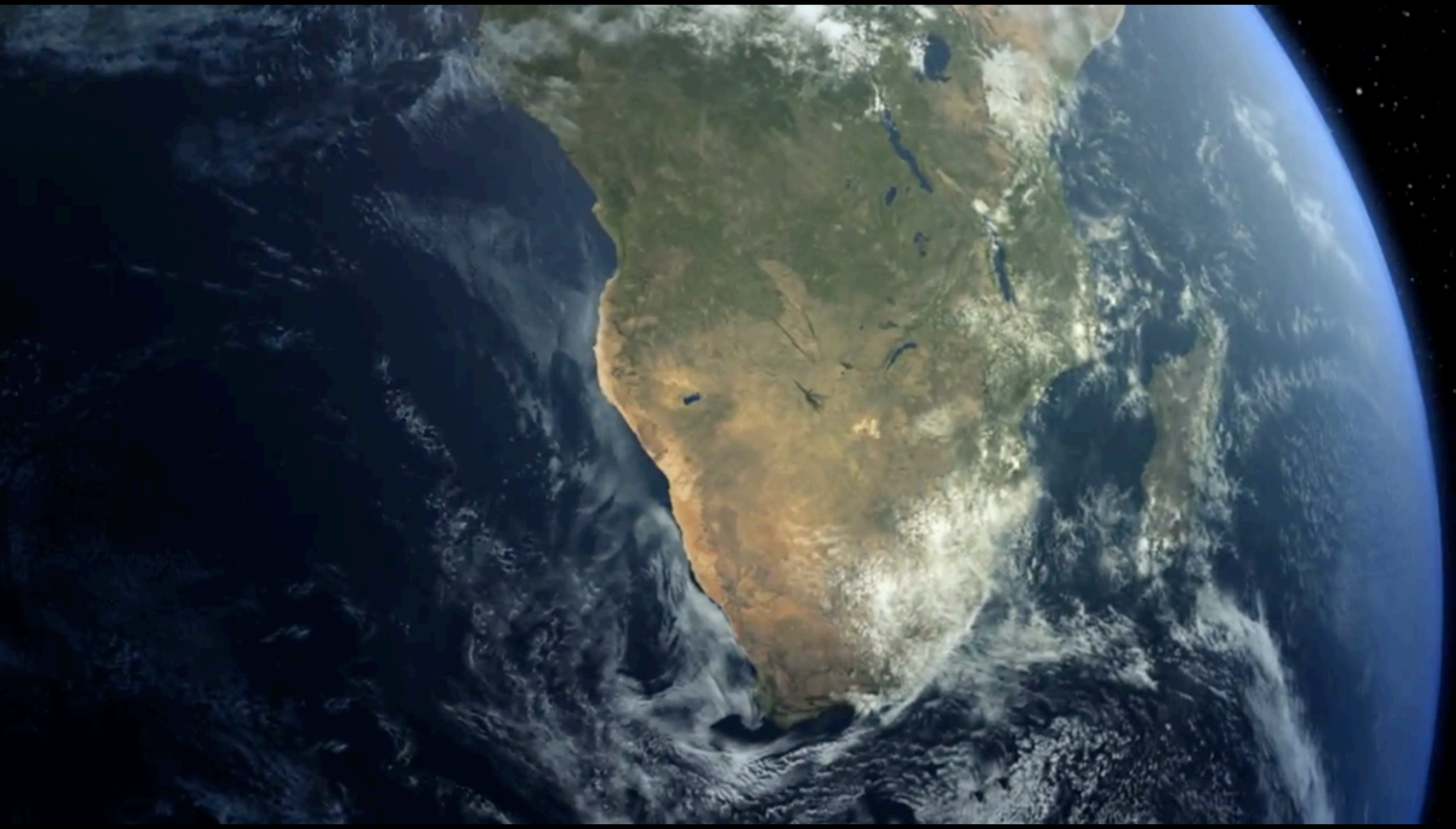
SKA1 MID



SKA LOW

APERTURE ARRAYS





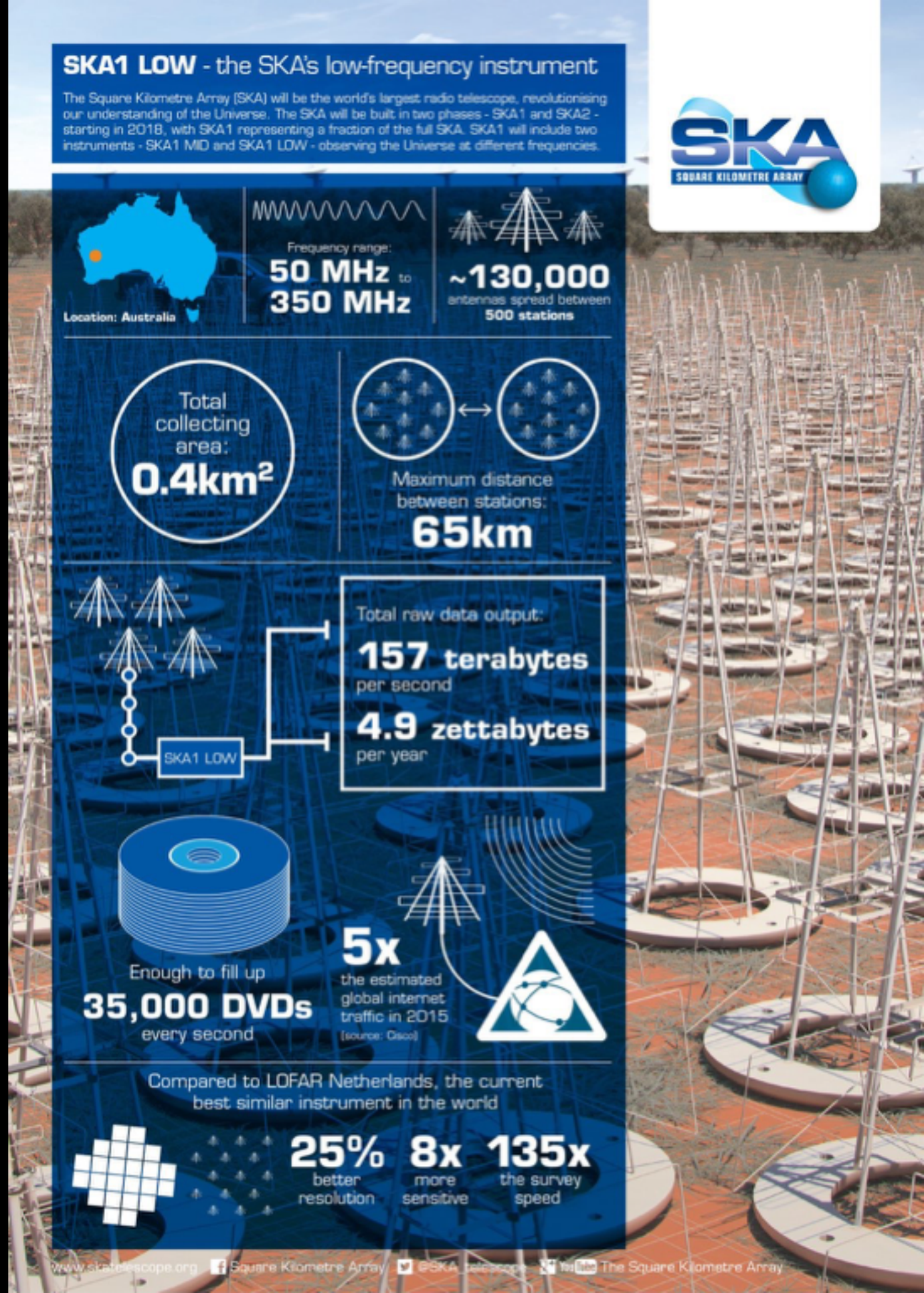
APERTURE ARRAY

SKA1 LOW

TERABYTE = 10^{12} BYTES

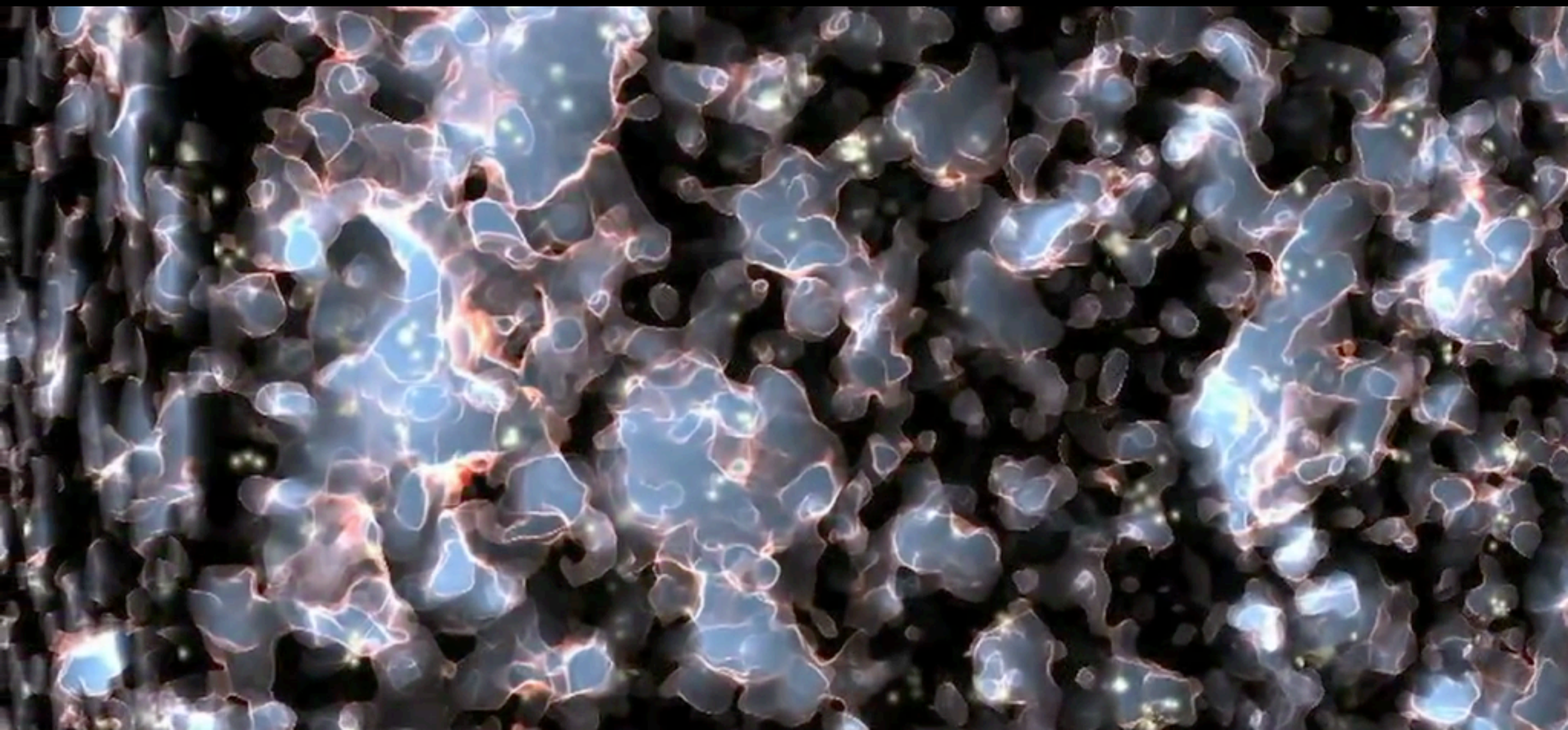
ZETTABYTE = 10^{21} BYTES

An "***Extreme Data***" project
- IBM



EPOCH OF REIONIZATION

- **HOW** THE FIRST STARS & GALAXIES FORMED
- **WHEN** THE FIRST STARS & GALAXIES FORMED
- REVEALED BY REDSHIFTED HYDROGEN



GRAVITATIONAL WAVES

- RIPPLES IN SPACE-TIME
- USE A NETWORK OF PULSARS TO DETECT THEM
- CAUSED BY INTER-ACTING SUPER-MASSIVE BLACK HOLES

COSMIC MAGNETISM

- DETERMINE THE ORIGIN OF COSMIC MAGNETIC FIELDS.
- USE RADIATION FROM THE EARLY UNIVERSE THAT HAS PASSED THROUGH MAGNETIC FIELDS.
- LOOK FOR ROTATION OF THE PLANE OF POLARISATION.

CRADLE OF LIFE

- LOOK FOR EMISSION FROM ORGANIC MOLECULES.
- IDENTIFY “EARTH-LIKE” PLANETS.
- ARE WE ALONE?

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Cosmic Rays with SKA(?)

SKA High Energy Cosmic Particles (HECP) Focus Group

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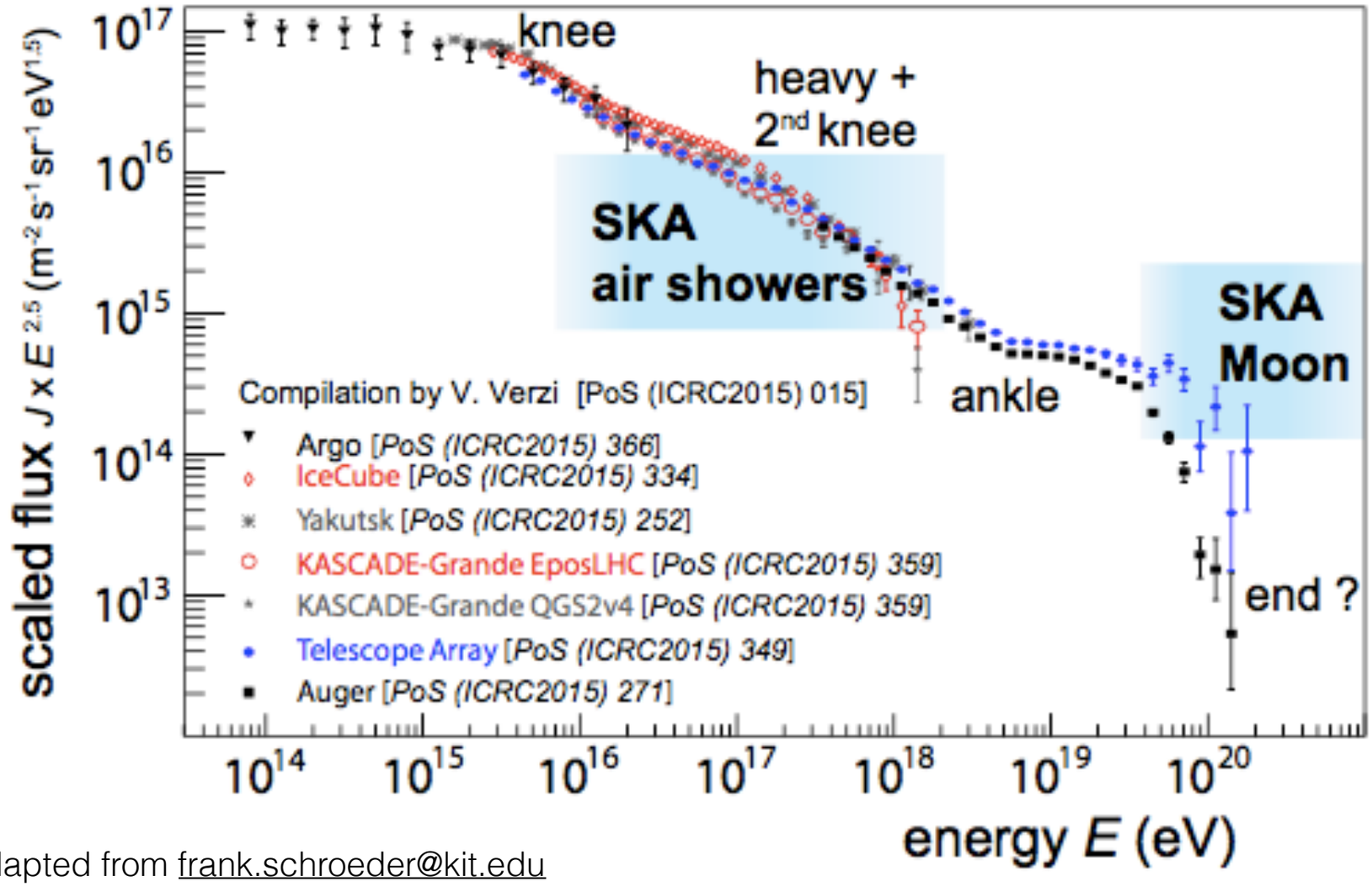

adapted from frank.schroeder@kit.edu

100 x more air shower events than LOFAR

~**10,000** air shower events per year > 10^{17} eV

Is the low-mass population dominated by protons (extra-galactic) or He nuclei (Galactic)?

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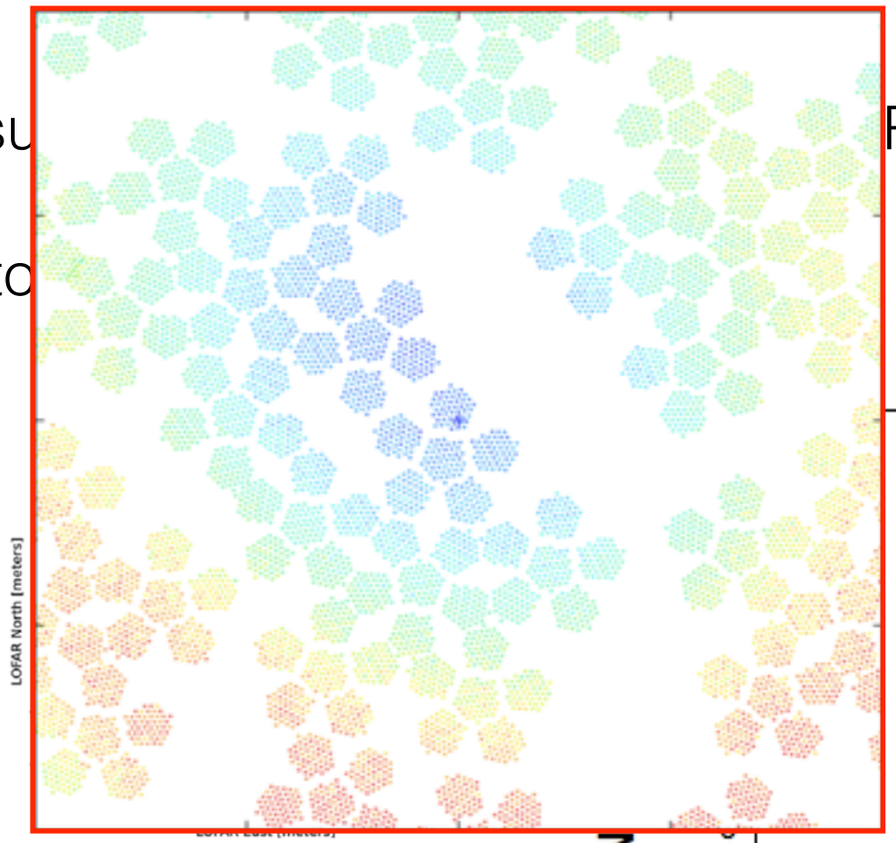
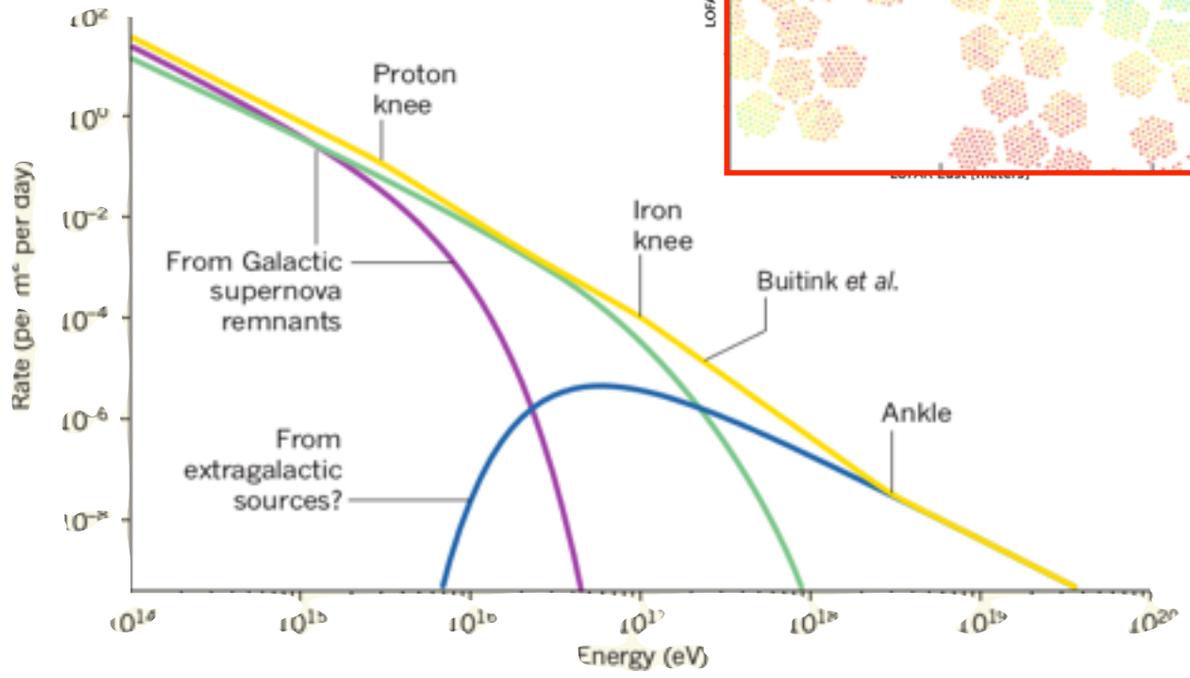
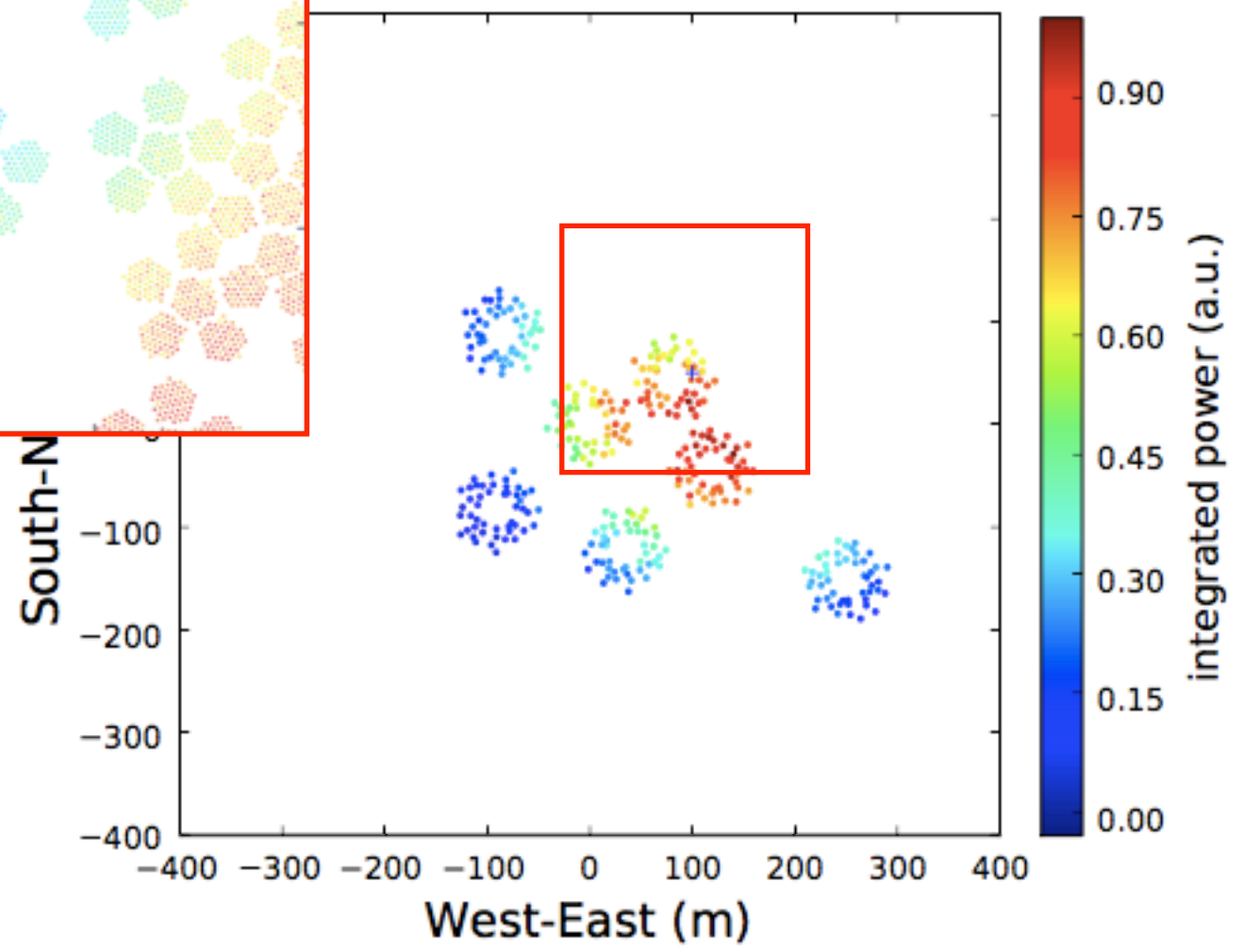
Cosmic Rays with SKA(?)

- LOFAR results su… Rs around $10^{17.5}$ eV
- Requires detecto…







arXiv1608.08869

Cosmic Rays with SKA(?)

The Economist

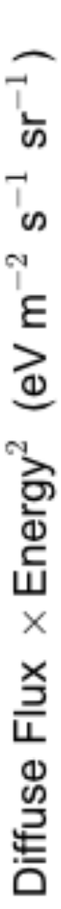
Cosmic-ray astronomy

Moonbeams

An intriguing proposal to study cosmic rays by looking at Earth's satellite

Oct 4th 2014 | From the print edition

THE Large Hadron Collider (LHC) is far and away the most powerful particle accelerator built by the hand of man. Yet it is puny compared to the most powerful particle accelerator of them all: the universe itself. Earth is under constant bombardment from cosmic rays (mostly atomic nuclei travelling at high velocity) that streak in from deep space, smash into the atmosphere and disintegrate in a puff of radiation and subatomic debris.



eV

arXiv1601.02980; arXiv1608.02408

Conclusions

- Now is an exciting time for radio astronomy;
- The technical advances that are being made in radio astronomy are advantageous for astroparticle physics;
- Community collaboration is key to maximising the science from these facilities