Building the World's Biggest Telescope:

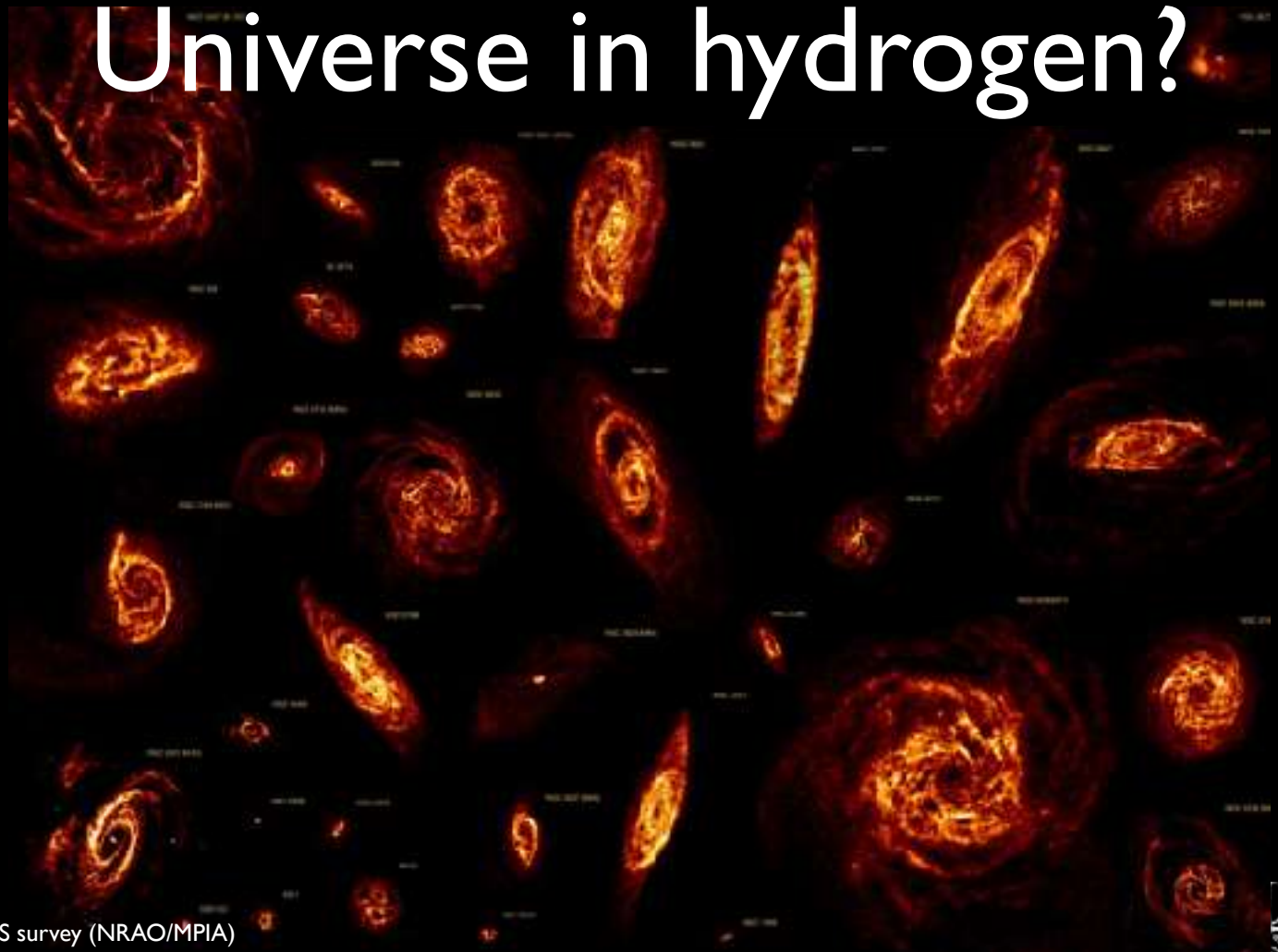
The **S**quare **K**ilometre **A**rray

Naomi McClure-Griffiths

The Australian National University

Australian National University

The 1991 concept: What does it take to read the history of the Universe in hydrogen?



Credit: THINGS survey (NRAO/MPIA)

Australian National University

A: A radio telescope 1 km^2 in area

Credit: SKAO/Swinburne Astronomy Productions

SKA Science

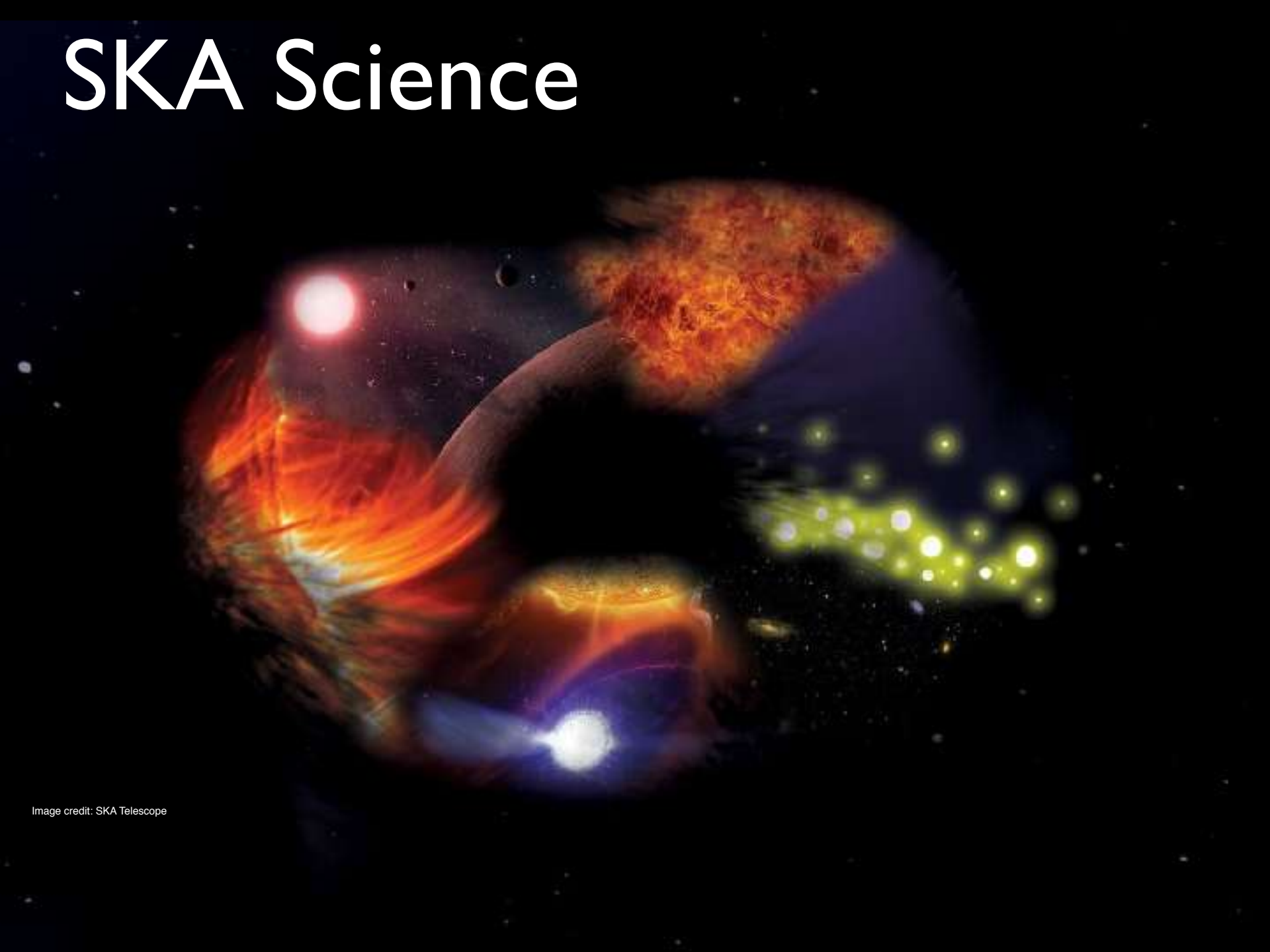


Image credit: SKA Telescope

SKA Science

The dawning of the cosmos -

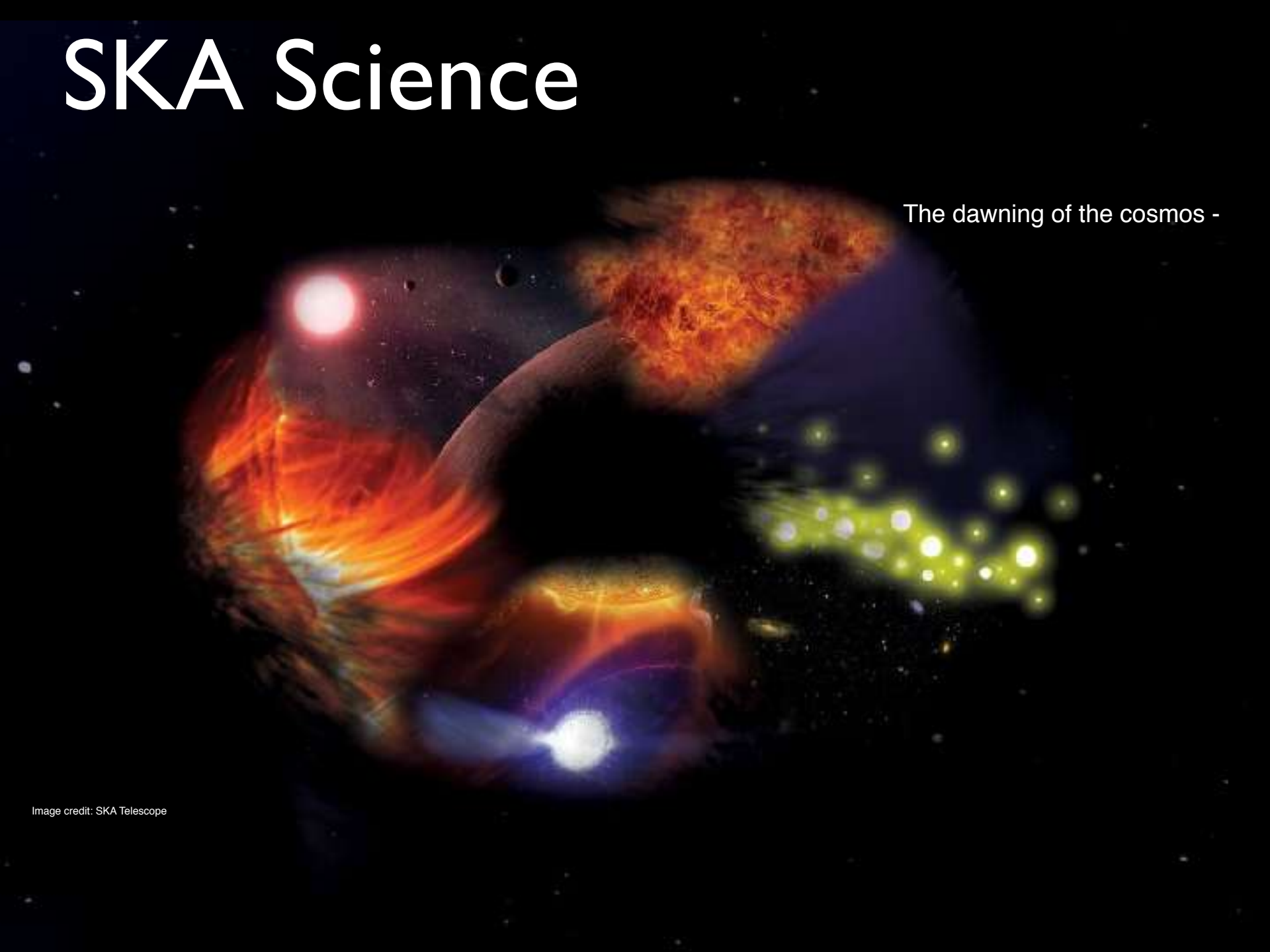
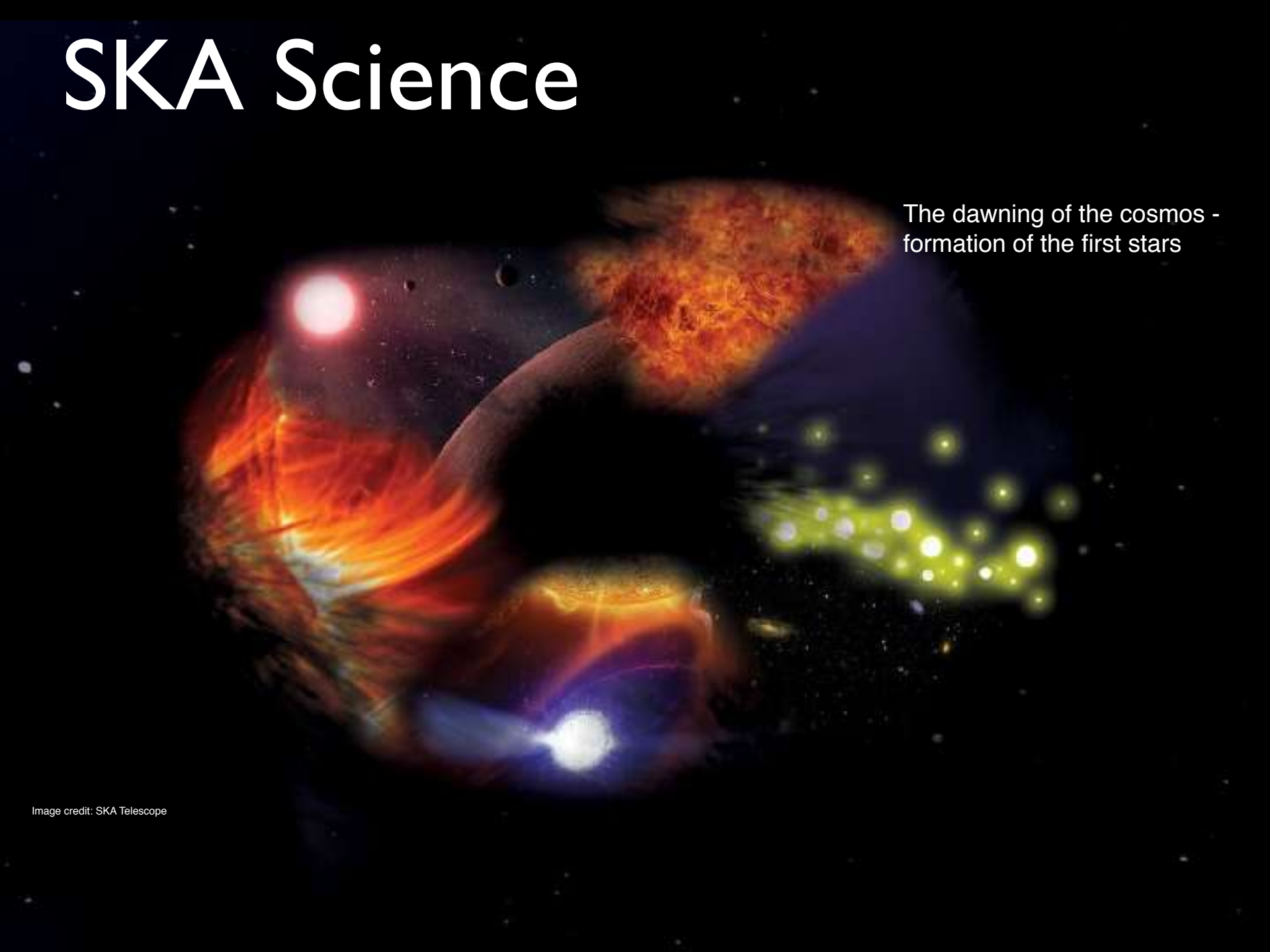


Image credit: SKA Telescope

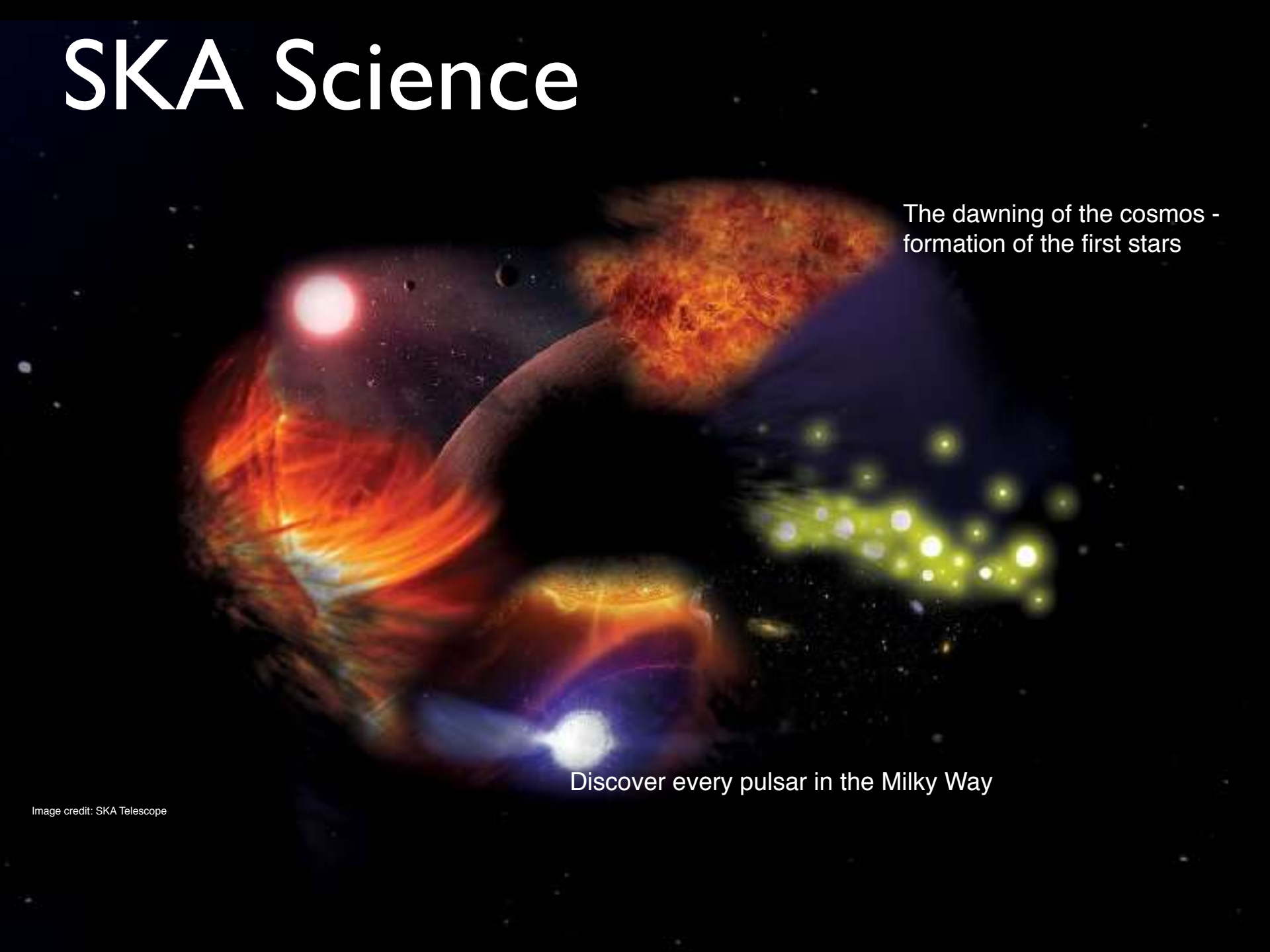
SKA Science



The dawning of the cosmos - formation of the first stars

Image credit: SKA Telescope

SKA Science

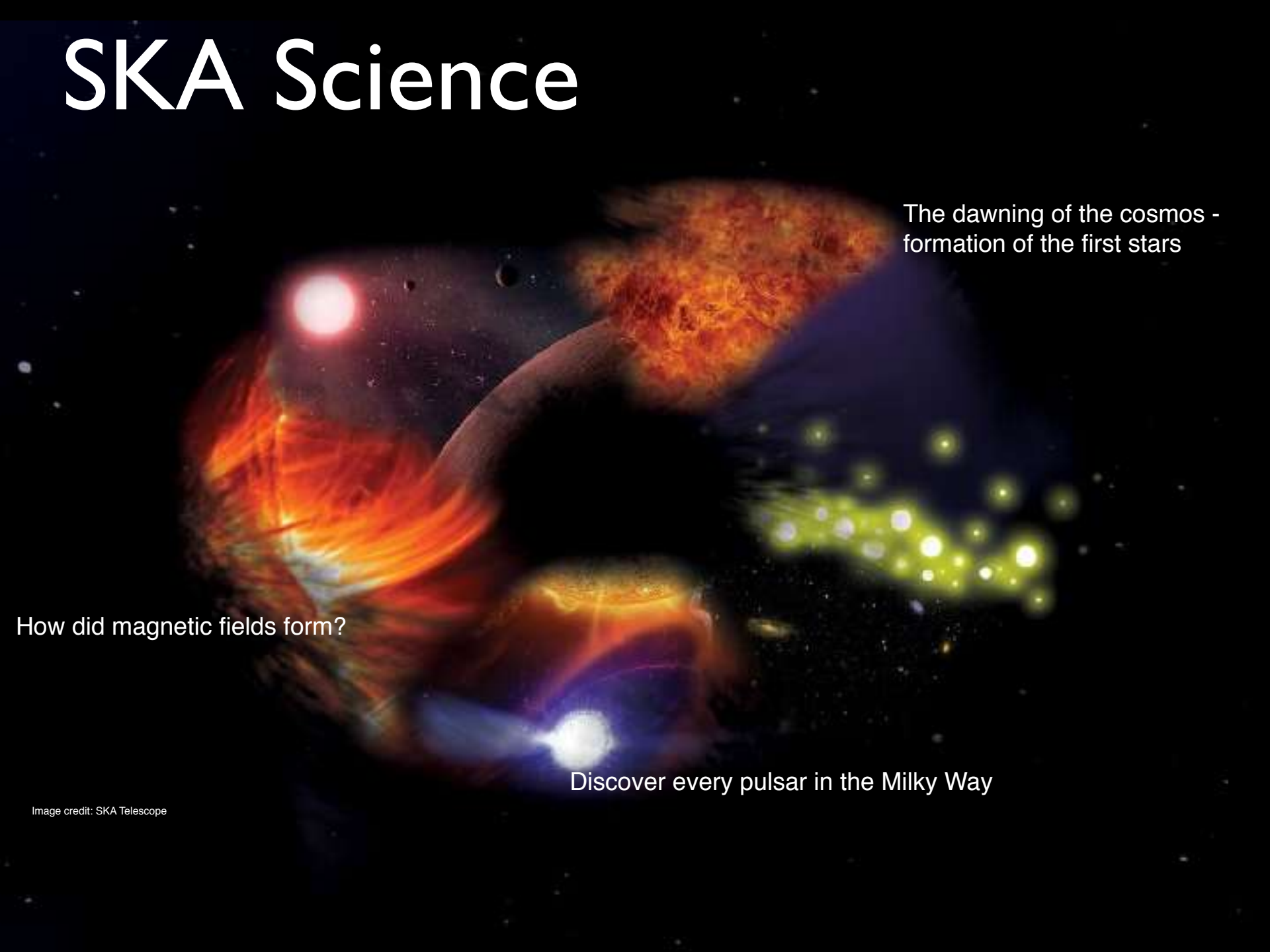


The dawning of the cosmos - formation of the first stars

Discover every pulsar in the Milky Way

Image credit: SKA Telescope

SKA Science



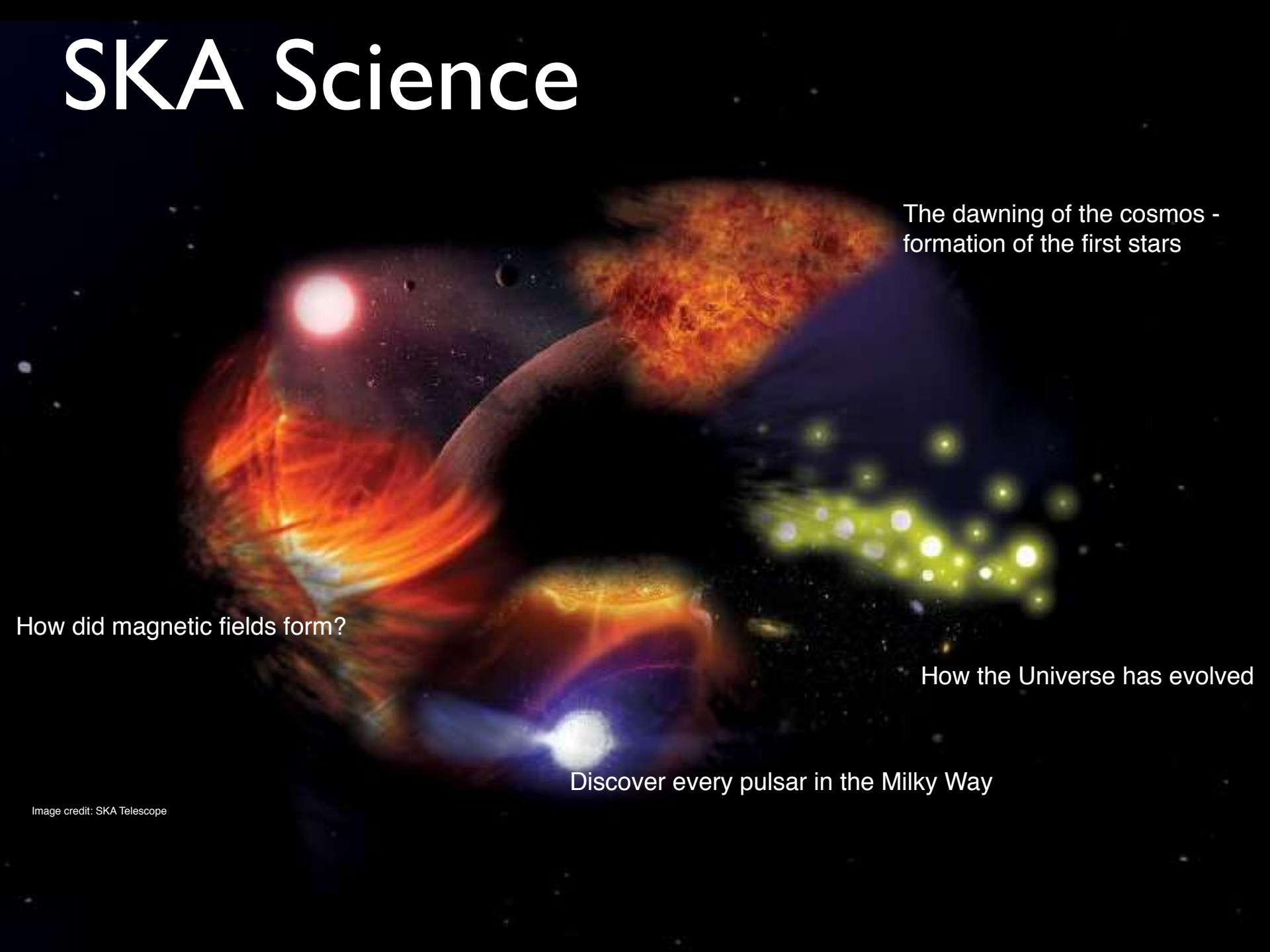
The dawning of the cosmos - formation of the first stars

How did magnetic fields form?

Discover every pulsar in the Milky Way

Image credit: SKA Telescope

SKA Science



The dawning of the cosmos - formation of the first stars

How did magnetic fields form?

How the Universe has evolved

Discover every pulsar in the Milky Way

Image credit: SKA Telescope

SKA Science

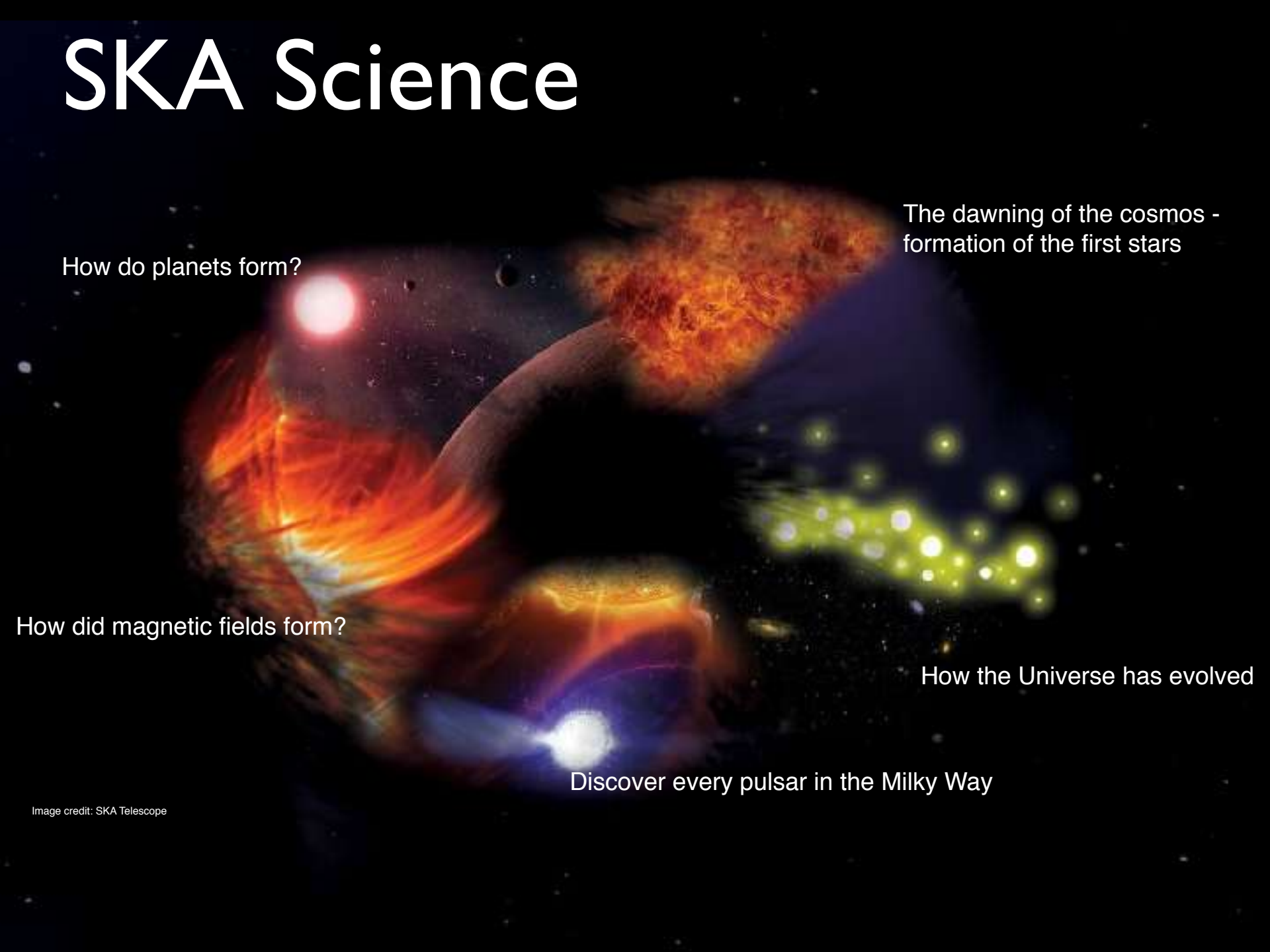


Image credit: SKA Telescope

SKA Science

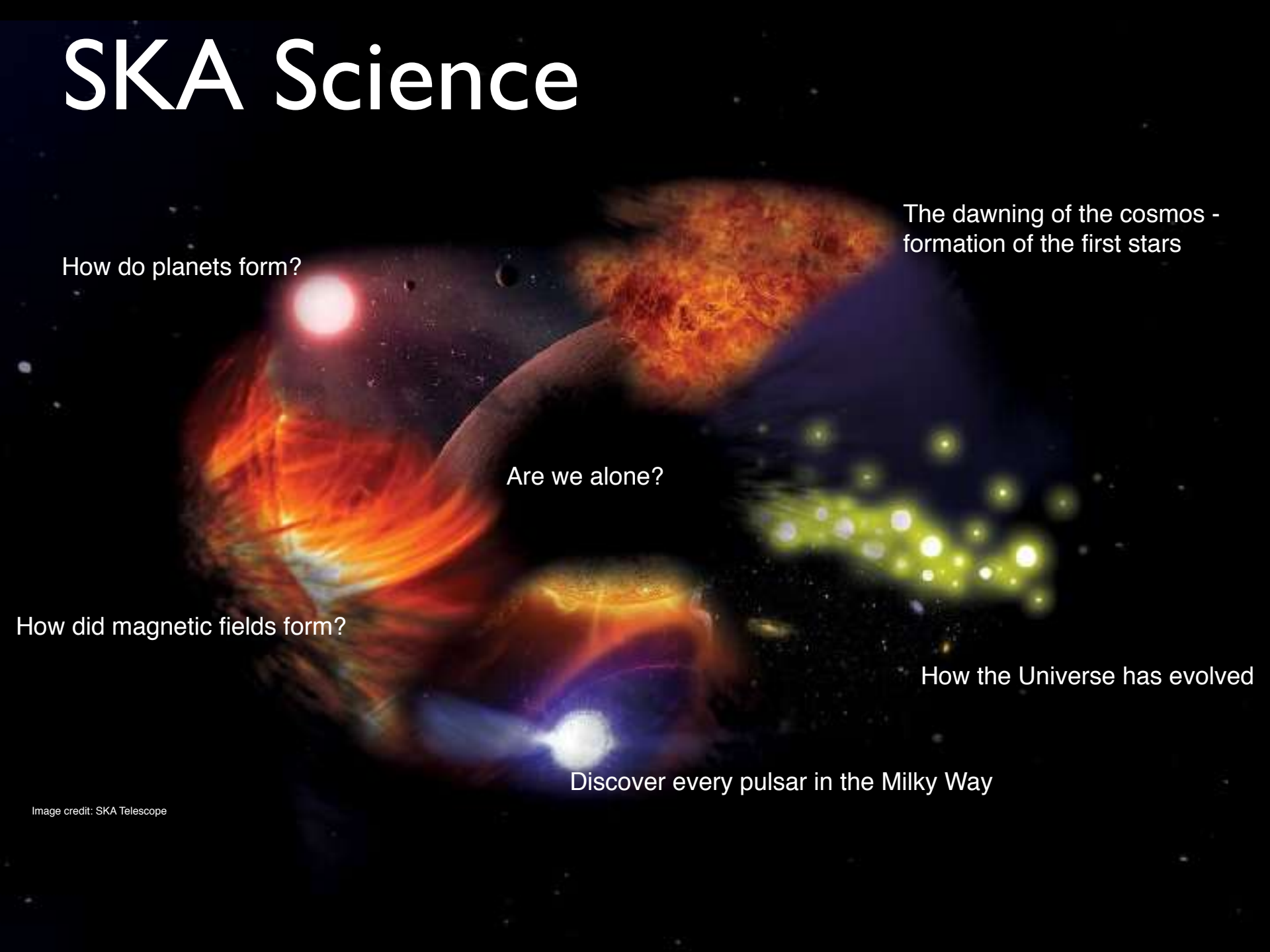
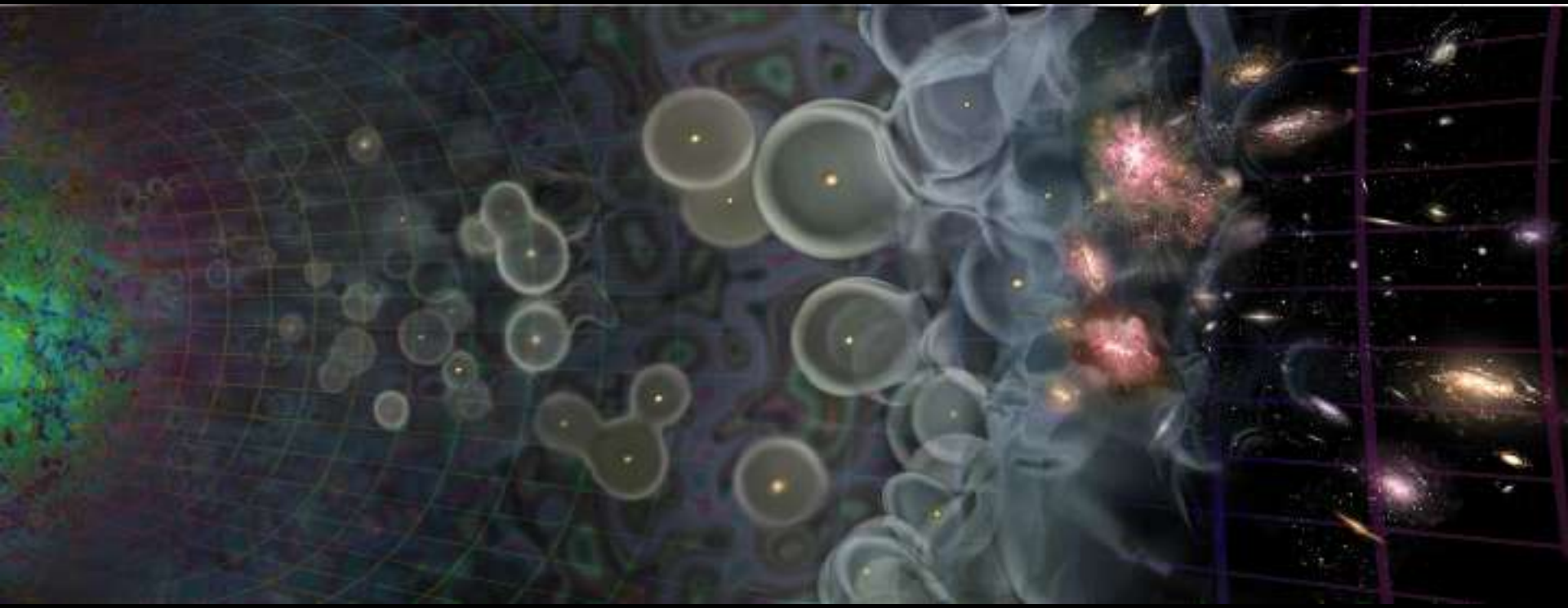


Image credit: SKA Telescope

The Cosmic Dawn

Credit: Loeb/CfA/UC Boulder



Big Bang **~500 Myr** **~1 Gyr** **~13 Gyr**

Australian National University

SKA2: Direct imaging of Cosmic Dawn (z = 12 - 30).

SKA1: Direct imaging of EoR structures (z = 6 - 12). Power spectrum of Cosmic Dawn

Credit: Alvarez, Kaehler & Abel

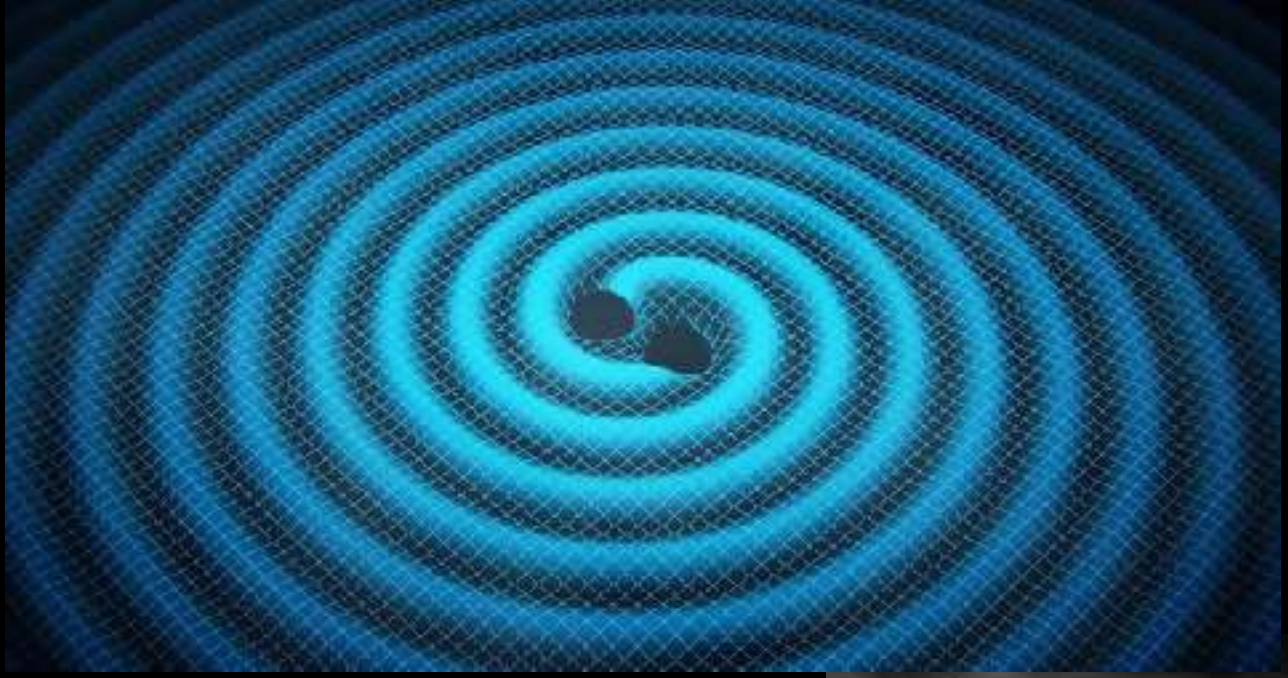
ralian National University

SKA2: Direct imaging of Cosmic Dawn (z = 12 - 30).

SKA1: Direct imaging of EoR structures (z = 6 - 12). Power spectrum of Cosmic Dawn

Credit: Alvarez, Kaehler & Abel

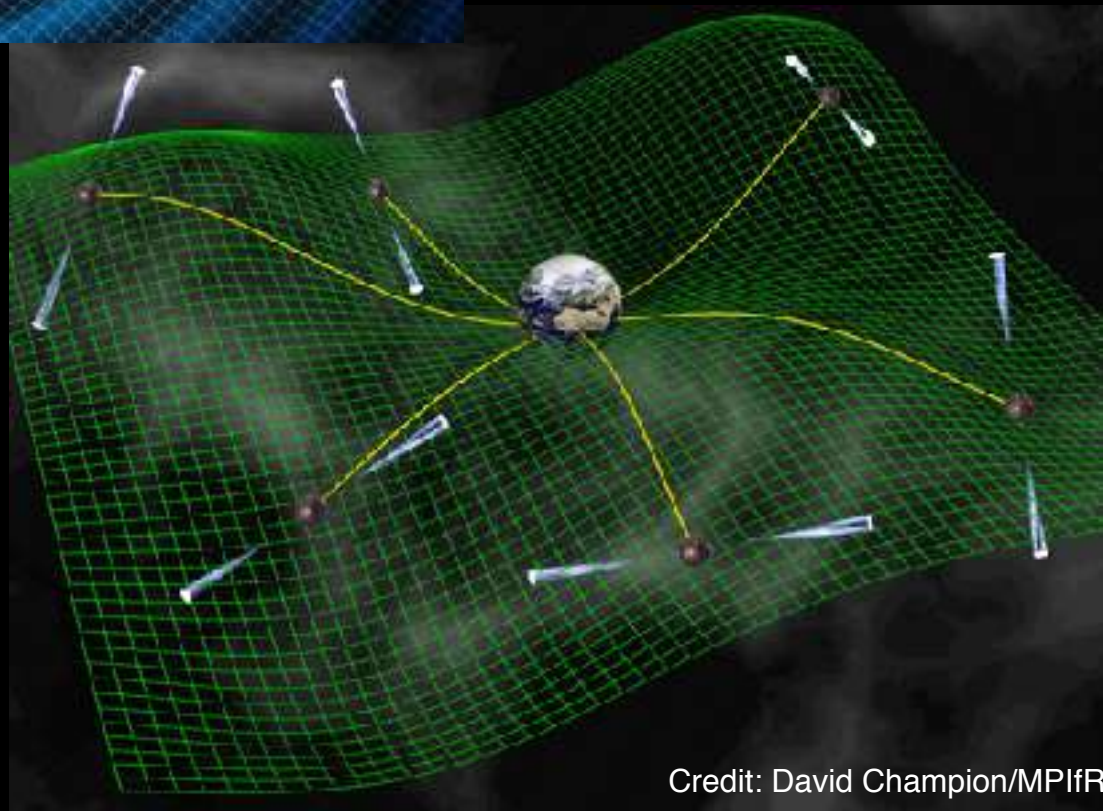
ralian National University



Testing Gravity

SKA1: 1st detection of nHz-stochastic gravitational wave background.

SKA2: Gravitational wave astronomy of discrete sources: constraining galaxy evolution, cosmological GWs and cosmic strings.

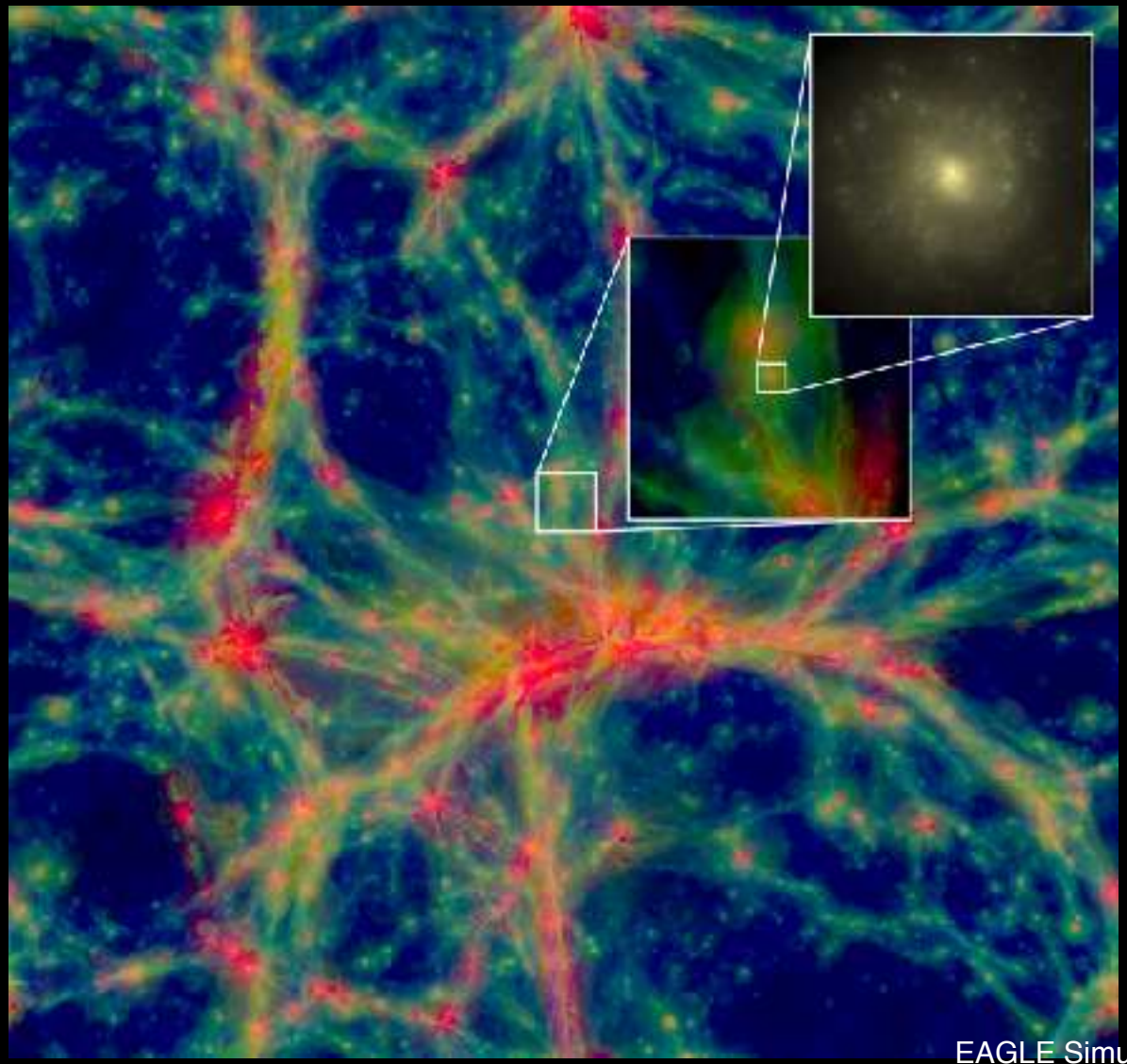


Credit: David Champion/MPIfR

Evolution of Galaxies: HI

SKA1: Gas properties of 10^7 galaxies, $\langle z \rangle \approx 0.3$, evolution to $z \approx 1$, ISM at 50pc resolution to 3Mpc

SKA2: Gas properties of 10^9 galaxies, $\langle z \rangle \approx 1$, evolution to $z \approx 5$, ISM at 50pc resolution to 10Mpc



EAGLE Simulation

Evolution of Galaxies: Continuum

Galaxies out to z~10

SKA1: Star formation rates (10 $M_\odot$/yr to z ~ 4)

SKA2: Star formation rates (10 $M_\odot$/yr to z ~ 10)

Hubble Deep Field (NASA)

Credit: Paul Alexander (Cambridge)

Evolution of Galaxies: Continuum

Galaxies out to z~10

SKA1: Star formation rates (10 $M_\odot$/yr to z ~ 4)

SKA

SKA2: Star formation rates (10 $M_\odot$/yr to z ~ 10)

Hubble Deep Field (NASA)

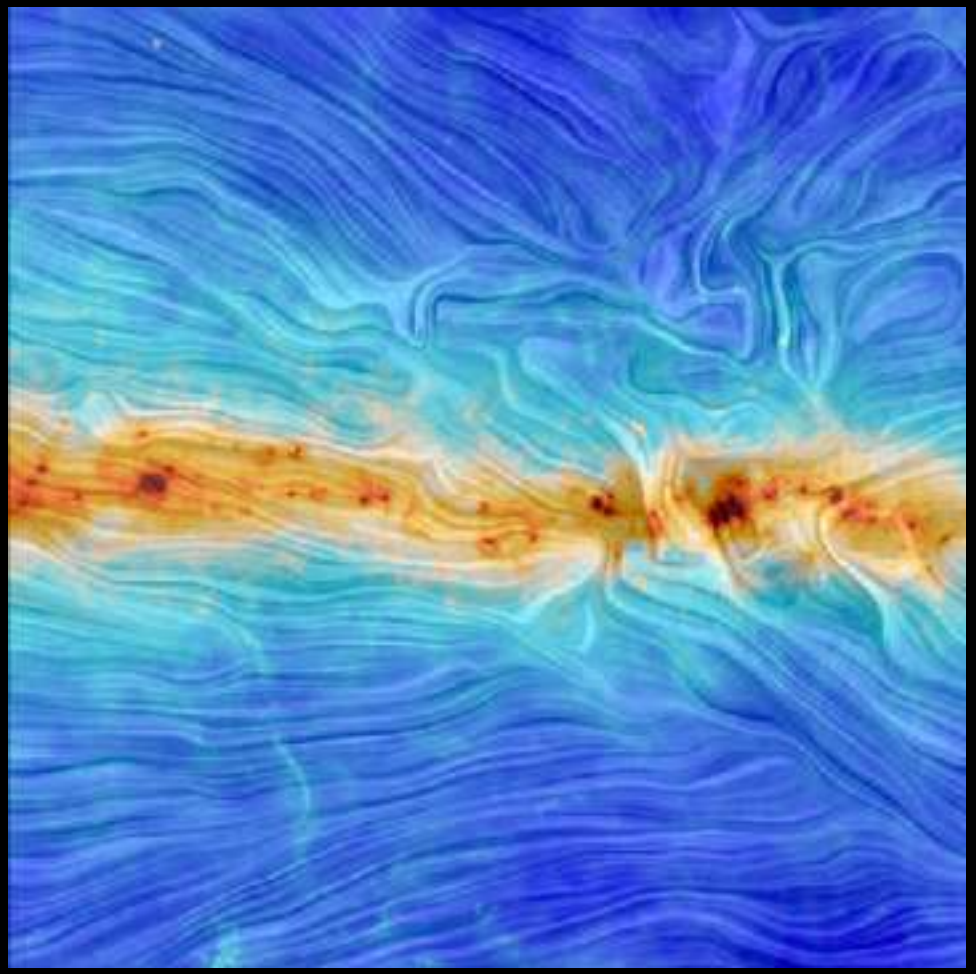
Credit: Paul Alexander (Cambridge)

Cosmic Magnetism

SKA1: The role of magnetism from sub-galactic to Cosmic Web scales, the RM-grid @ 300/deg^2

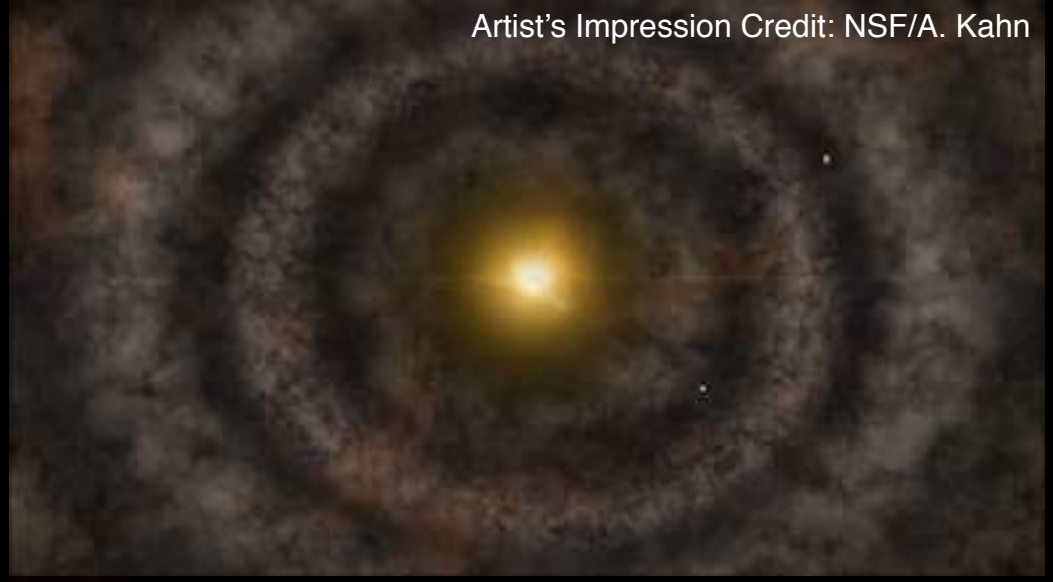
Credit: TRACE satellite

Credit: ESA/Planck



SKA2: The origin and amplification of cosmic magnetic fields, the RM-grid @ 5000/deg^2

Cradle of Life



Artist's Impression Credit: NSF/A. Kahn

ALMA Data Credit: ALMA (NRAO,ESO,NAOJ)/C. Broagan/B. Saxton

SKA1: Proto-planetary disks; imaging inside the snow/ice line (@ < 100pc)

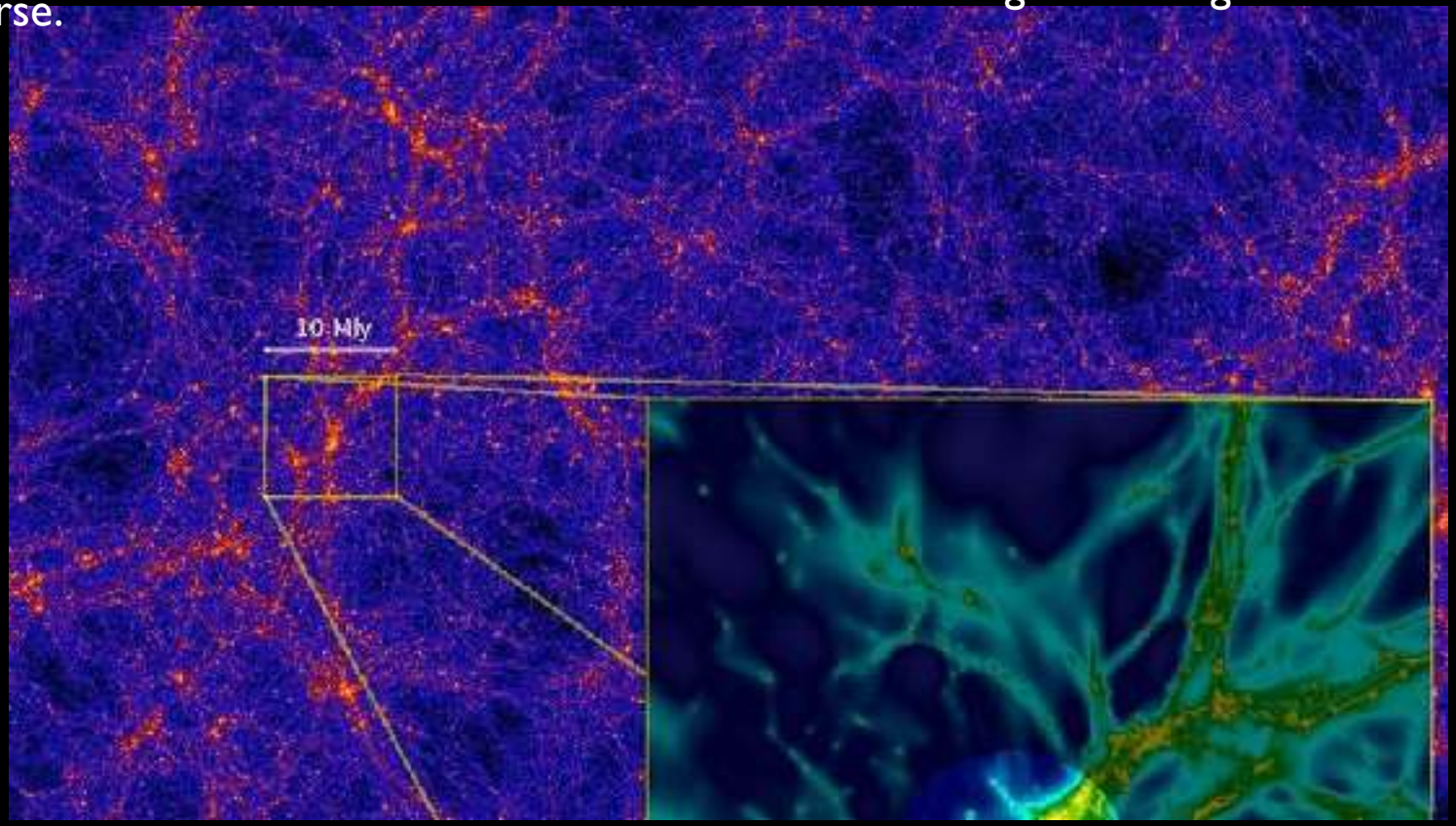
SKA2: Proto-planetary disks; sub-AU imaging (@ < 150pc)

Australian National University

Things that go bang

SKA1: Use fast radio bursts to uncover the missing "normal" matter in the universe.

SKA2: Fast radio bursts as unique probes of fundamental cosmological parameters and intergalactic magnetic fields.



A. Klypin, J. Primack, S. Cantalupo

The enormity of SKA Science

Science WGs

- Current SWGs represent a wide range of scientific areas:
  - Extragalactic Spectral Line (non-HI)
  - Our Galaxy
  - Solar, Heliospheric & Ionospheric Physics
  - Epoch of Reionization
  - Cosmology
  - Extragalactic Continuum (galaxies/AGN, galaxy clusters)
  - Cradle of Life
  - HI galaxy science
  - Magnetism
  - Pulsars
  - Transients
- Technique focused Working Group:
  - VLBI
- Topical Focus Group:
  - High Energy Cosmic Particles

Membership open to any active researcher with willingness to contribute at appropriate level

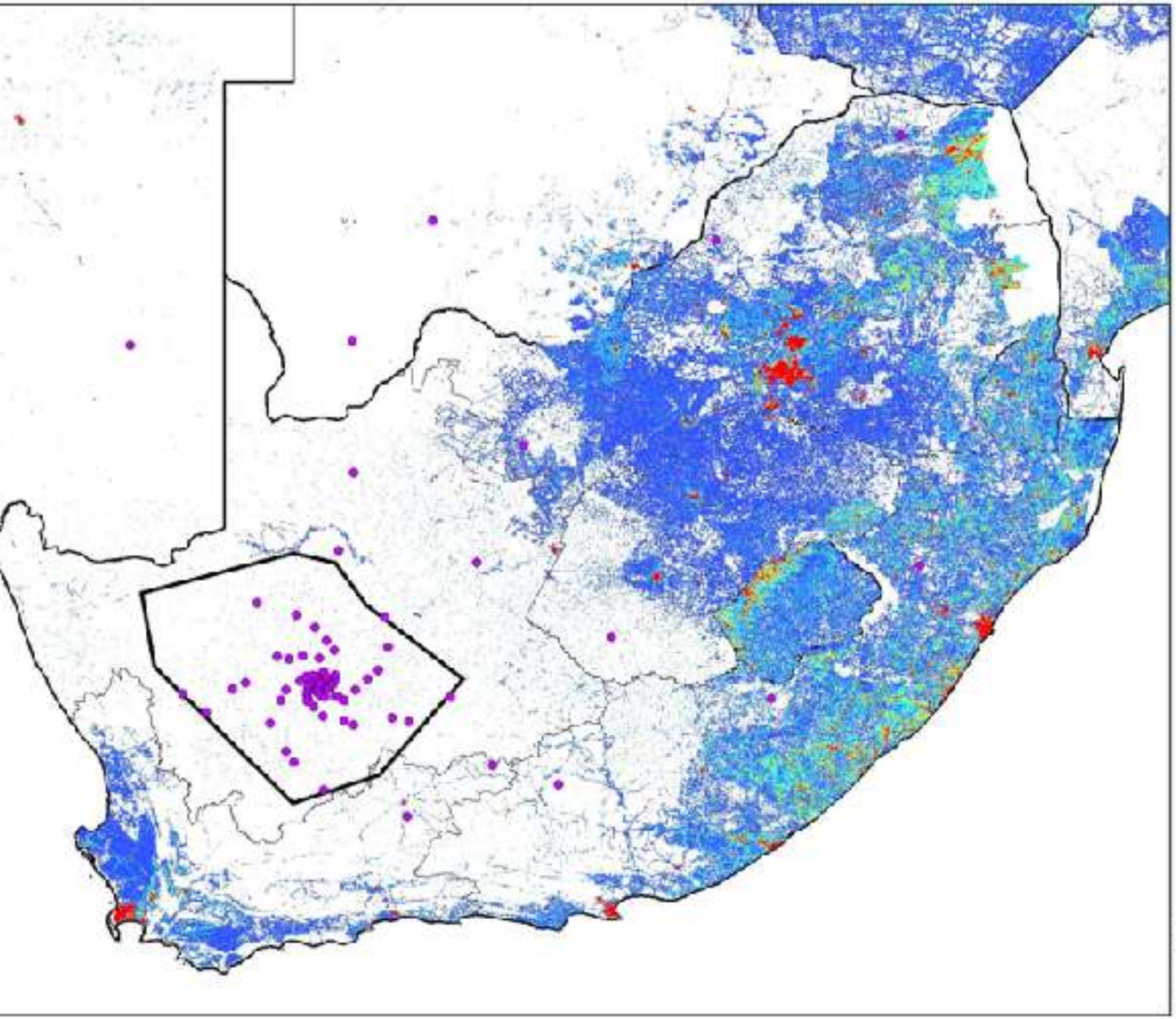
Anyone can nominate themselves by contacting the current SWG Chairperson (per web site) or SKA Project Scientist/Science Director

A potted history of SKA

- Original idea 1991
- SKA meetings (1993 -)
- SKA Science Book v1 2004
- SKA science - Key Science Projects (2005-ish)
- Site selection 2012
- SKA Phase I Baseline design - 2013
- SKA Phase I cost-cap 650M€ 2013
- Re-baseline 2014/2015 - new SKA1 concept
- SKA Science Book v2 2015
- Deployment baseline at 674M€ 2017
- *SKA1 starts construction 2019*
- *SKA1 early science start around 2022*
- *SKA2 ?*

Steps to building the world's biggest telescope…

Select a site…

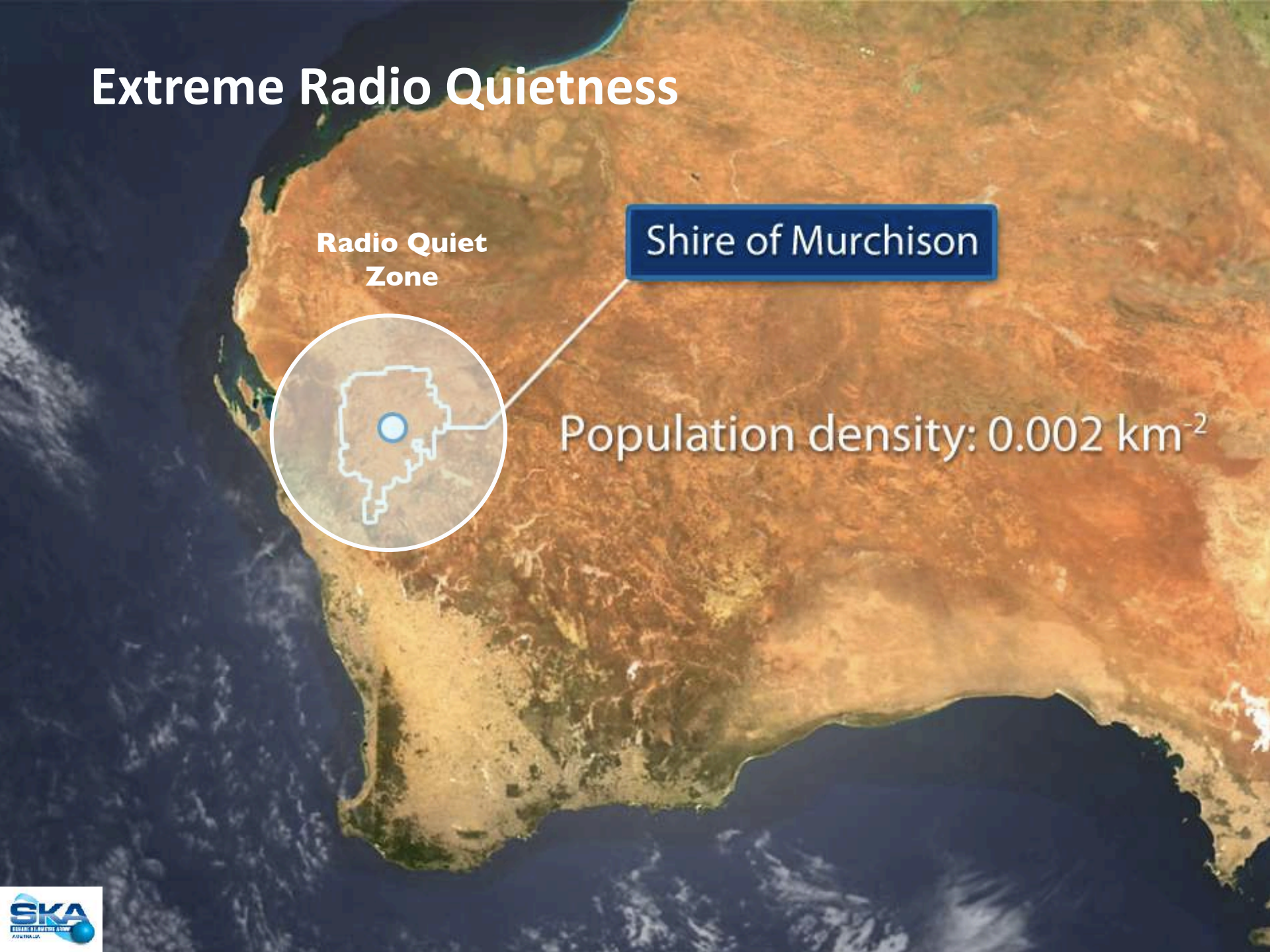


Contact:
Dr Adrian Tiplady
SKA South Africa
17 Baker Street
Rosebank
2196
South Africa
Tel: +27 11 442 2434
Fax: +27 11 442 2434
Email: atiplady@ska.ac.za


Murchison Radio-Astronomy Observatory (MRO)
S26° 42′ 15″, E116° 39′ 32″

Extreme Radio Quietness

Extreme Radio Quietness



Two sites…


Zimbabwe
Namibia
Botswana
Swaziland
Lesotho

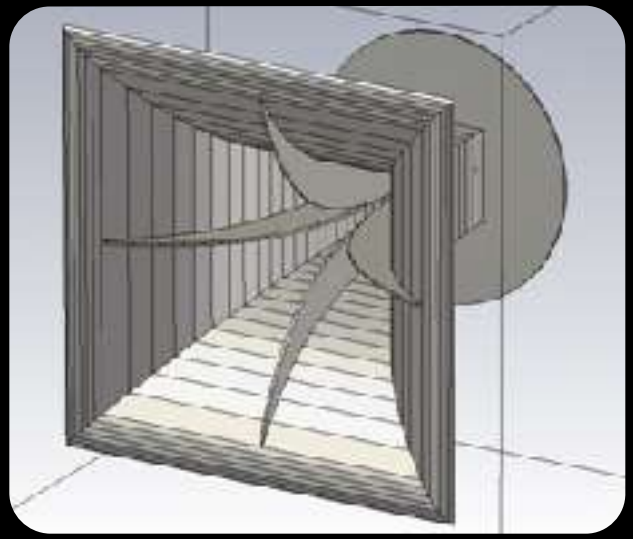
Two sites…

WWW.SKA.GOV.AU

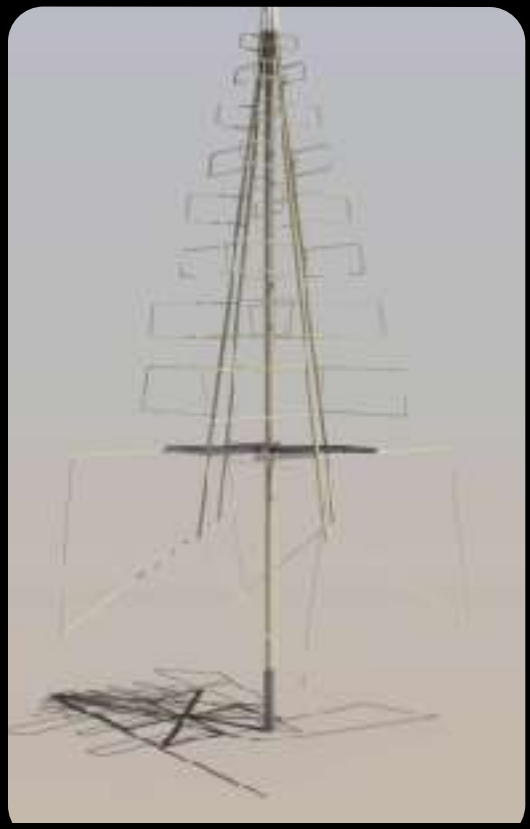

WWW.SKA.GOV.AU

Design what to build…

Credit: SKA SA



Credit: Caltech WBSPF for SKA AIP



Credit: SKAO

SKA Stages

SKA1 : 2018-204

130,000 Low Frequency Aperture Arrays

175 15m dishes

SKA2: 2025+

>250,00 LFAA

2500 dishes

SKA1-LOW

Australian National University

SKA1-LOW

- To be built in Western Australia
- Operate 50 - 350 MHz
- 130,000 elements, 512 stations of 256 antennas
- Maximum baseline ~60-80km (5 arcmin resolution at 100 MHz), centrally concentrated

SKA1-LOW & SKA2-LOW

SKA1-LOW

SKA2-LOW

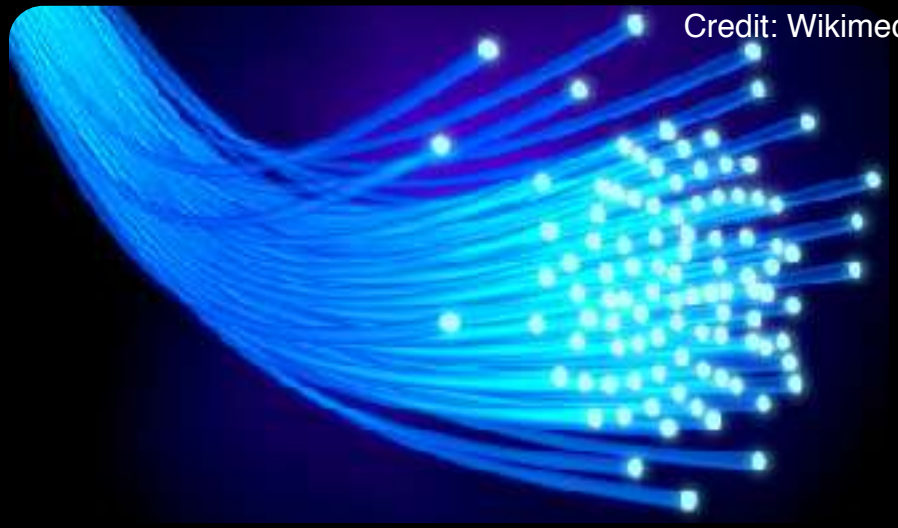
SKA1-MID

Australian National University

SKA1-MID

- To be built in South Africa
- 133 x 15m antennas plus MeerKAT's 64 x 13.5m antennas
- Three frequency bands: 0.95 - 1.76 GHz (band 2), 4.6 - 14 (24) GHz (band 5), (0.35 - 1.1 GHz (band 1)
- Maximum baseline 150 km (possibly 120km)

Move and crunch the data…



Credit: Wikimedia

Credit: CSIRO

Credit: IVEC

Australian National University

Data flow through the SKA

SKA1-MID

8.8 Tb/s

~5 Tb/s

130 - 300 PB/yr

Users

7.2 Tb/s

SKA1-LOW

~2 Pb/s

Australian National University

How does SKA1 compare with the world's biggest radio telescopes?

SKA1 LOW

Australia

419,000m²

~130,000 antennas

MWA

2,500m²

2048 antennas

LOFAR

52,000m²

24,000 antennas

GMRT

48,000m²

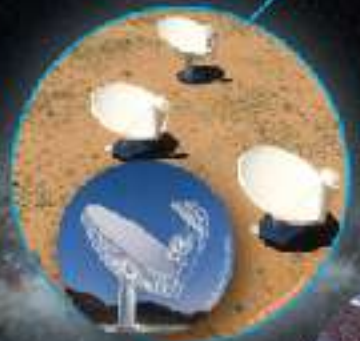
30 dishes

SKA1 MID

South Africa

33,000m²

~200 dishes



ASKAP

4,000m²

36 dishes

MeerKAT

9,000m²

64 dishes

JVLA

13,200m²

27 dishes

Lovell

4,500m²

76m dish

Effelsberg

7,800m²

100m dish

Parkes

3,200m²

64m dish

GBT

7,800m²

100m dish

NRT

7,000m²

300m x 35m antenna

FAST

71,000m²

500m dish

Arecibo

42,000m²

305m dish

ALMA

6,500m²

66 dishes

ARRAYS

SINGLE DISHES

LOW FREQUENCIES

MID FREQUENCIES

HIGH FREQUENCIES

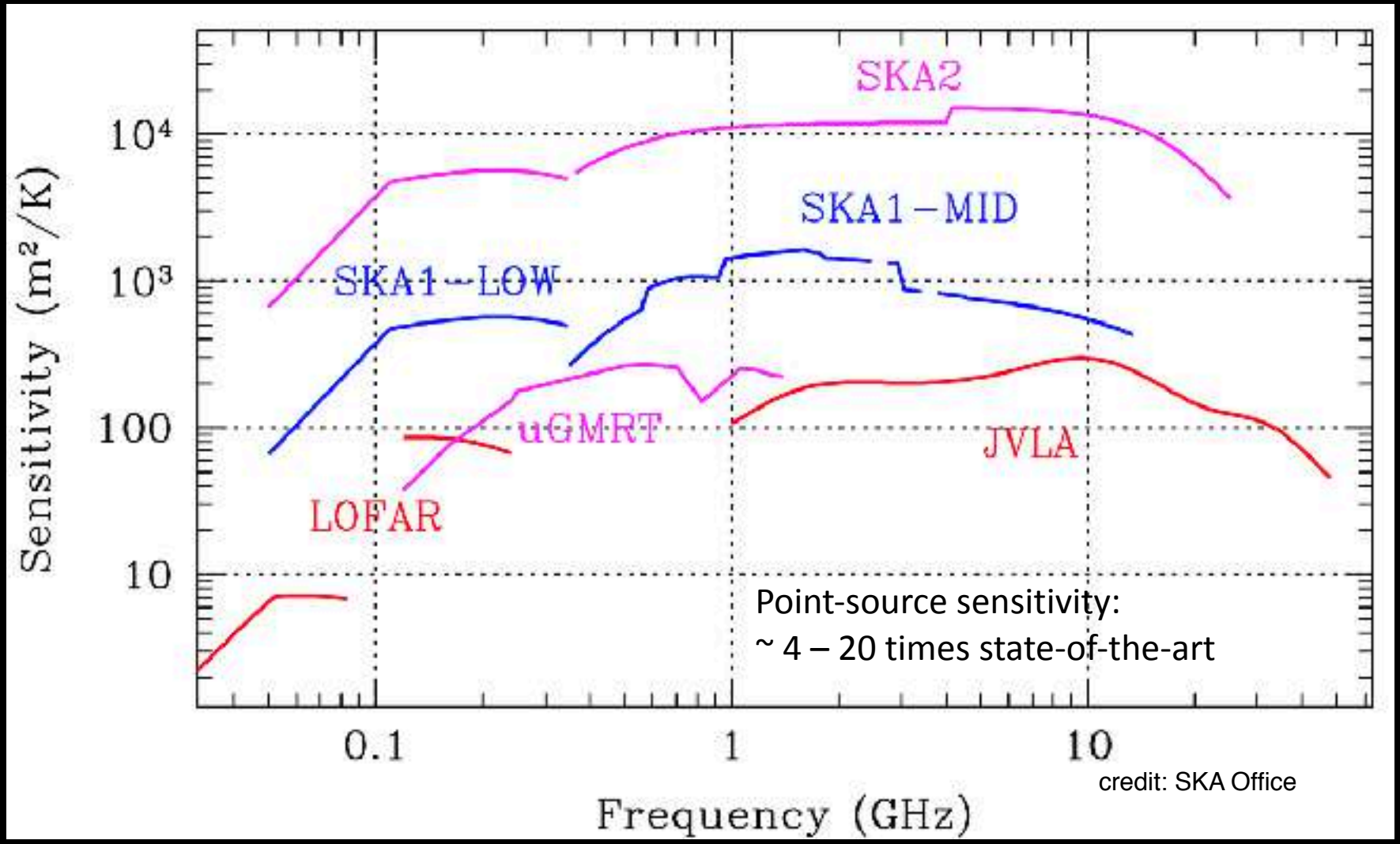
The Square Kilometre Array (SKA) will be the world's largest radio telescope, revolutionising our understanding of the Universe. The SKA will be built in two phases - SKA1 and SKA2 - starting in 2018, with SKA1 representing a fraction of the full SKA. SKA1 will include two instruments - SKA1 MID and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

A telescope's capacity to receive faint signals - called sensitivity - depends on its collecting area, the bigger the better. But just like you can't compare radio telescopes and optical telescopes, comparison only works between telescopes working in similar frequencies, hence the different categories above.

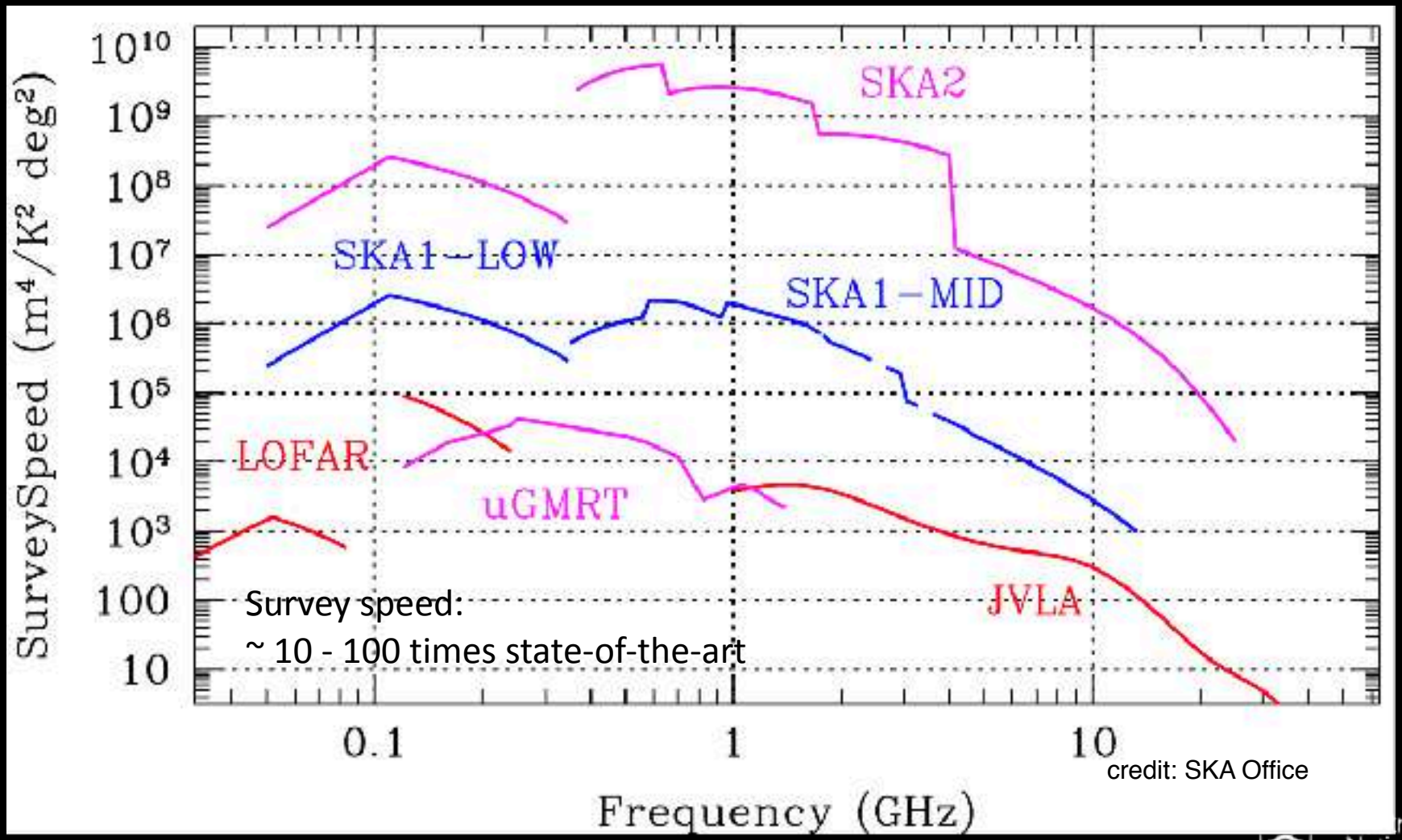
The collecting area is just one aspect of a telescope's capability though. Arrays like the SKA have an advantage over single dish telescopes by being spread over long distances, they simulate a virtual dish the size of that distance and so can see smaller details in the sky, this is called resolution.

www.skatelescope.org | Square Kilometre Array | @SKA_telescope | The Square Kilometre Array

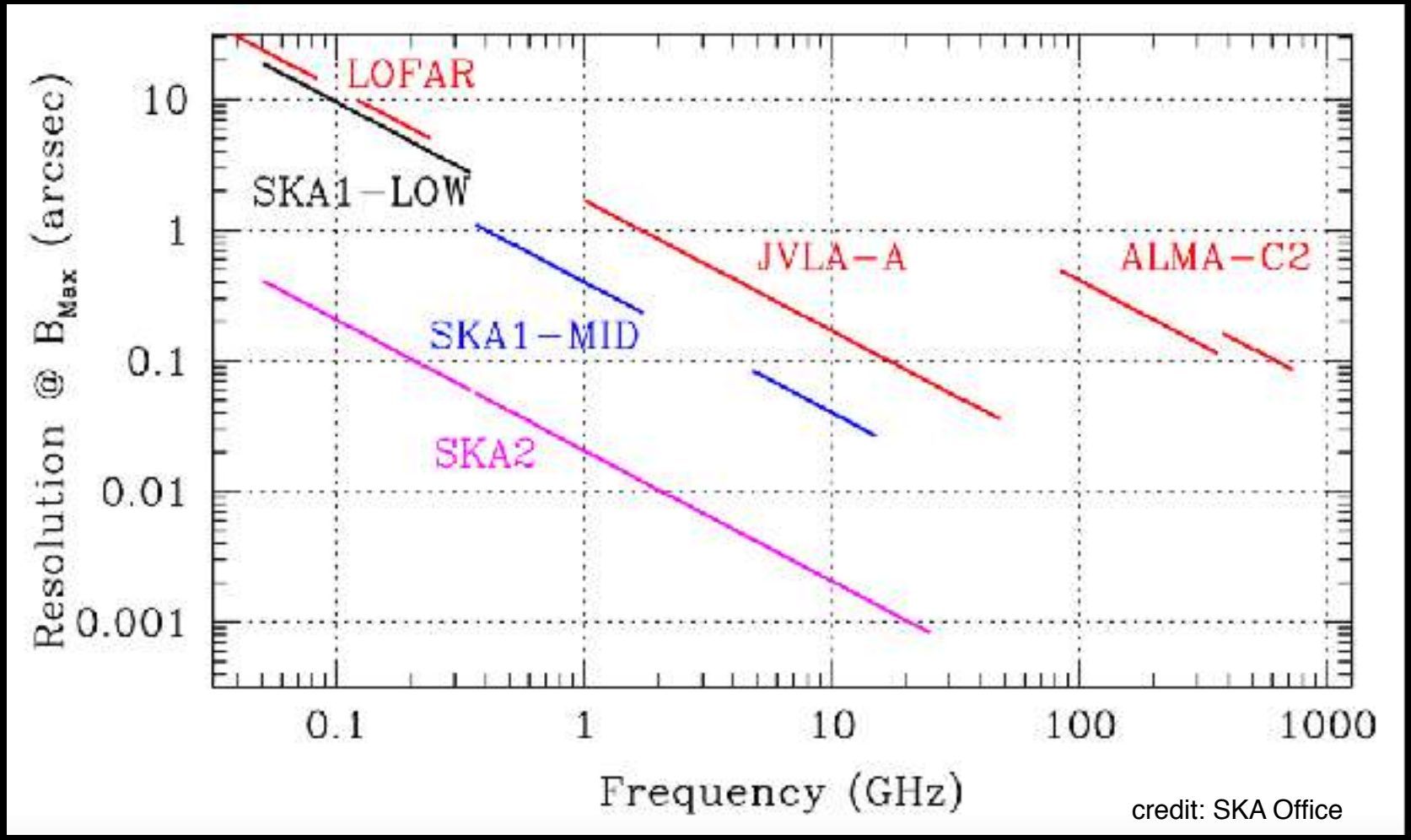
Sensitivity Comparison



Survey Speed Comp.



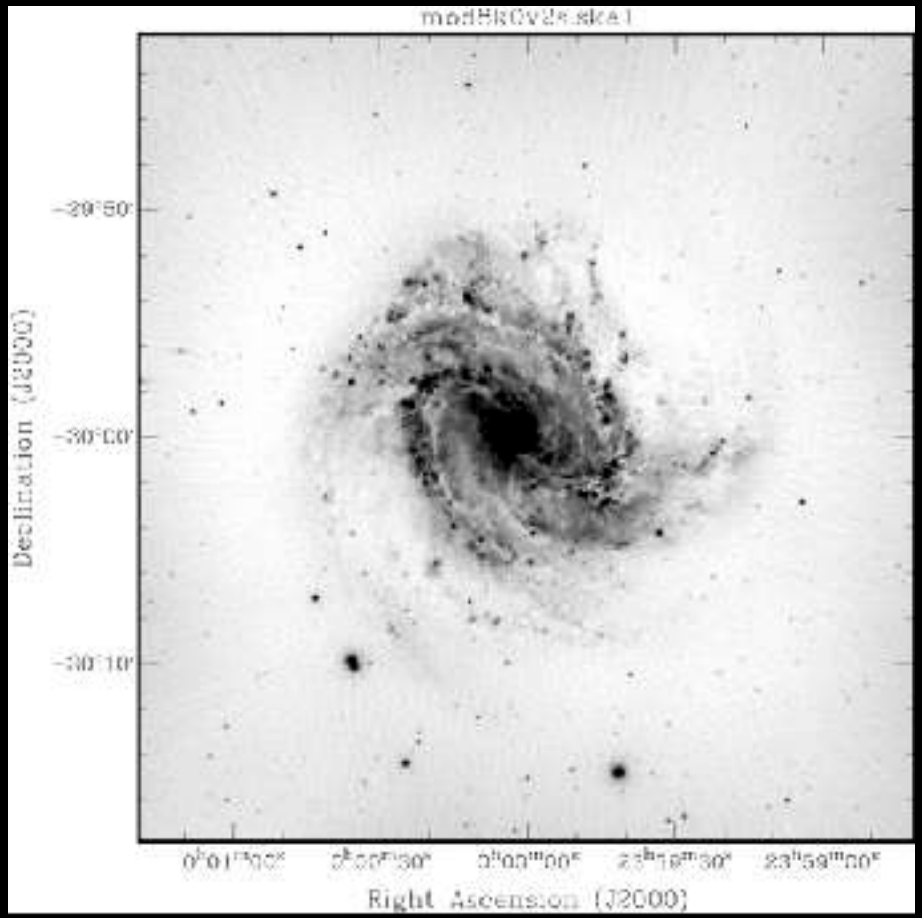
Resolution Comparison



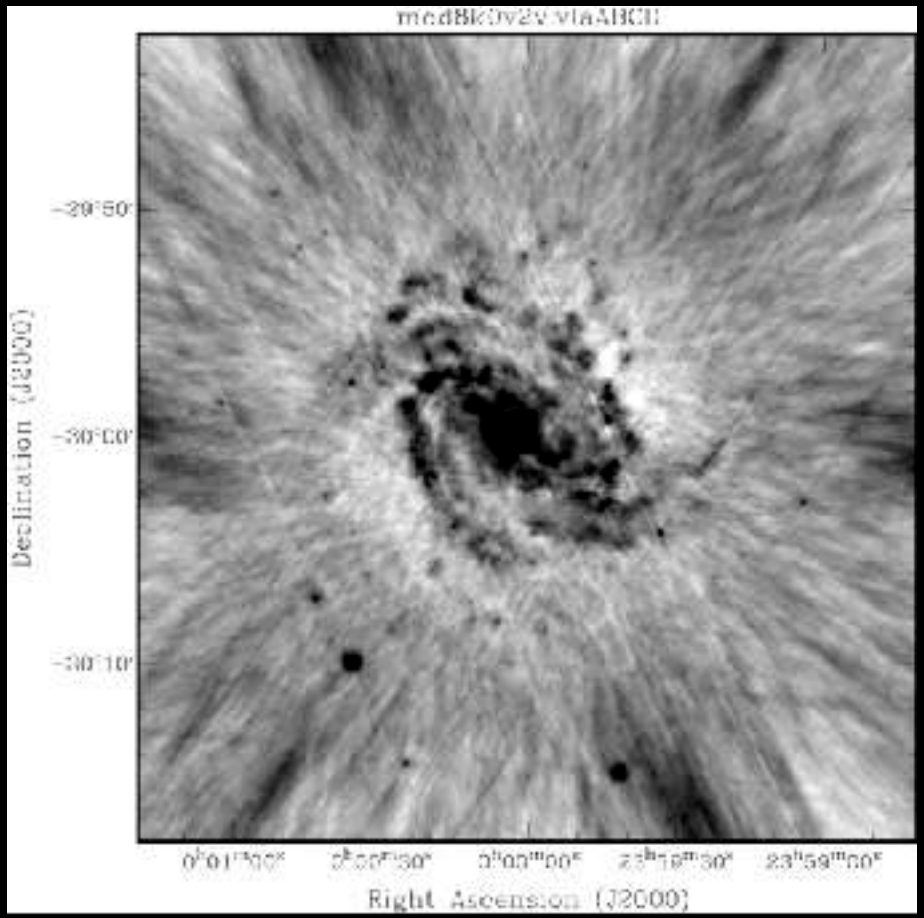
credit: SKA Office

Image Quality Comp

SKA1-Mid snap-shot



VLA A+B+C+D snap-shot



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

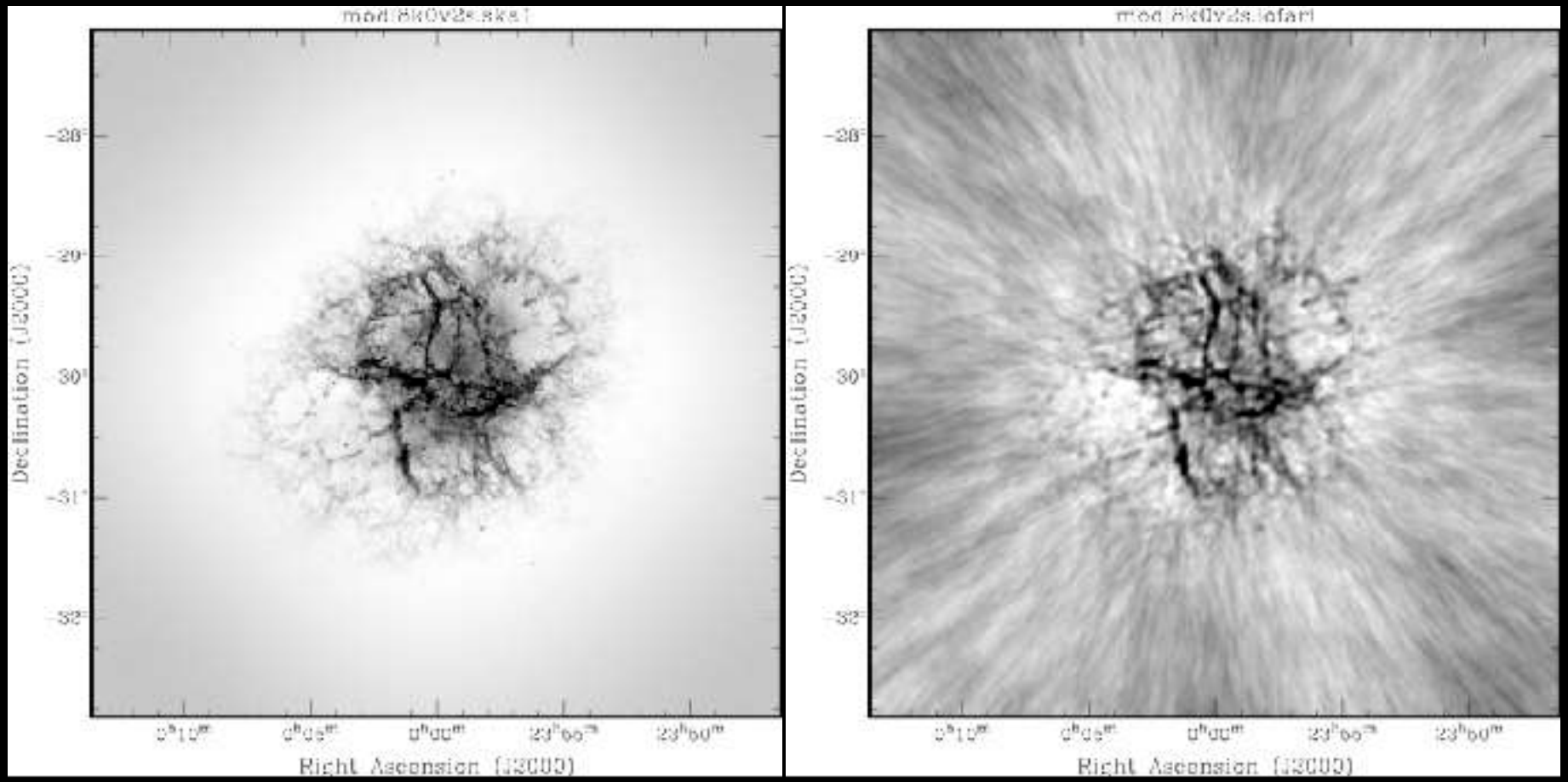
credit: SKA Office

Australian National University

Image Quality Comp

SKA1-LOW snap-shot

LOFAR-INTL snap-shot



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

credit: SKA Office

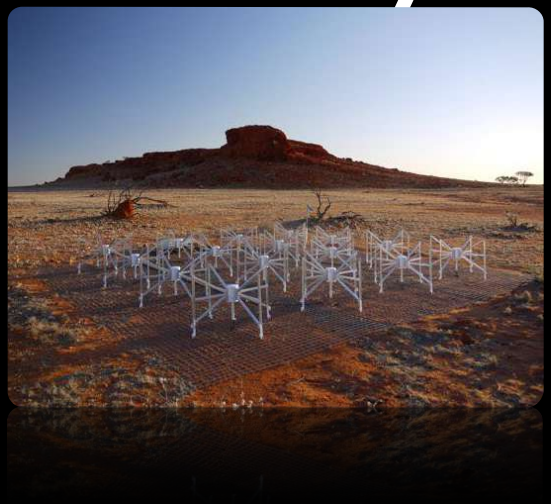
Australian National University

The first steps…

Murchison Widefield Array

Credit: MWA/ICRAR

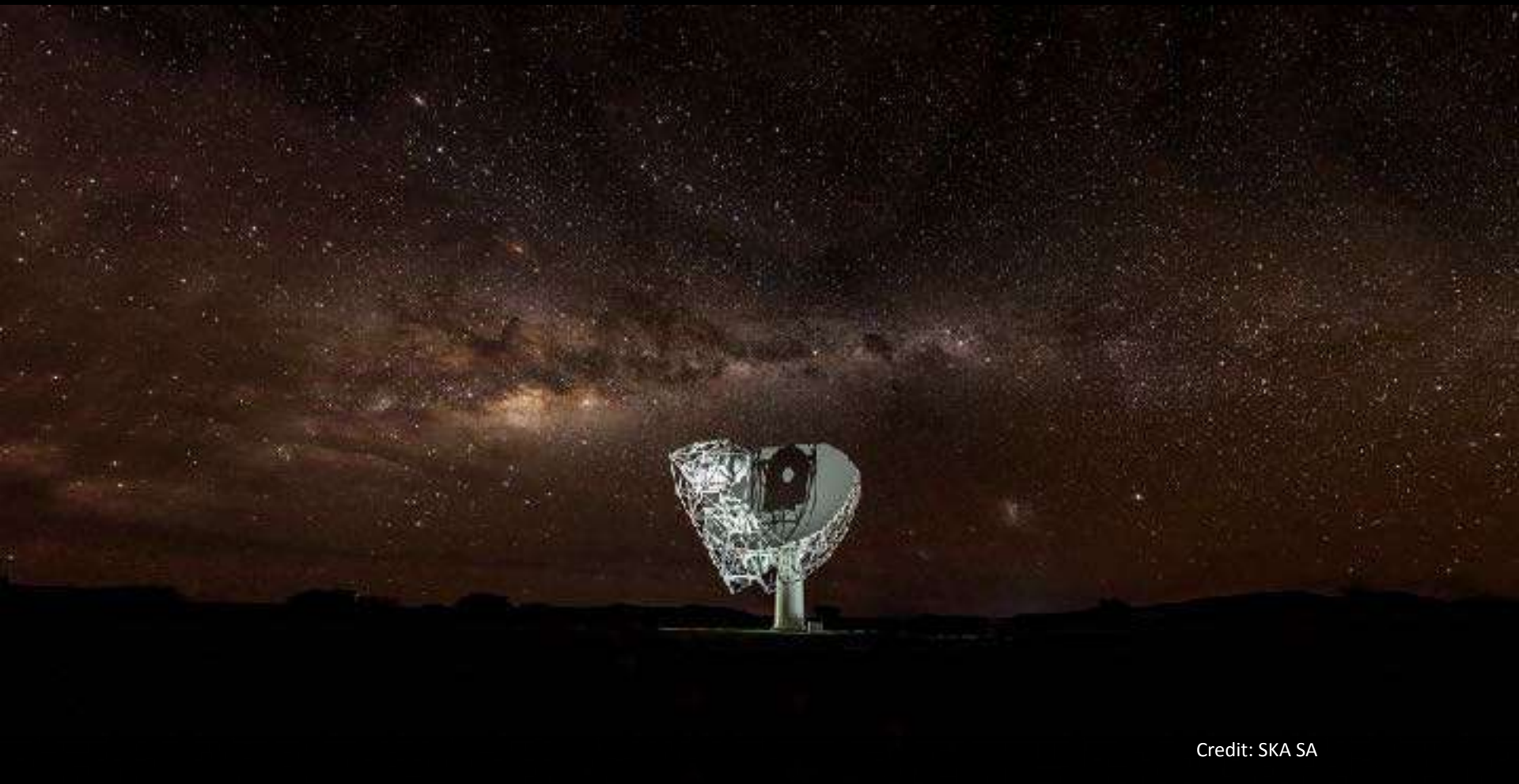
Murchison Widefield Array



- 128 tiles
- 80 -300 MHz
- 30 MHz instantaneous BW
- 112 tiles within 1.5 km
- remainder to max baseline 3 km
- Phase II - additional 128 tiles

Credit: MWA/ICRAR

MeerKAT



Credit: SKA SA

MeerKAT

Credit: SKA SA

MeerKAT

- 64 dishes
  - 13.m offset gregorian
  - FOV ~ 1 degree
- Frequency bands:
  - 0.90 - 1.67 GHz (now)
  - 0.58 - 1.015 GHz (by mid2018)
  - 1.75 - 3.5 GHz (by late 2018)
- L-band Tsys/eta: 22 - 24 K!!
- Max baseline: 8 km
  - Min baseline: 29 m
  - 48 antennas (75% of collecting area) in inner 1km

Credit: SKA SA

Australian SKA Pathfinder

Credit: Alex Cherney/CSIRO

Australian SKA Pathfinder

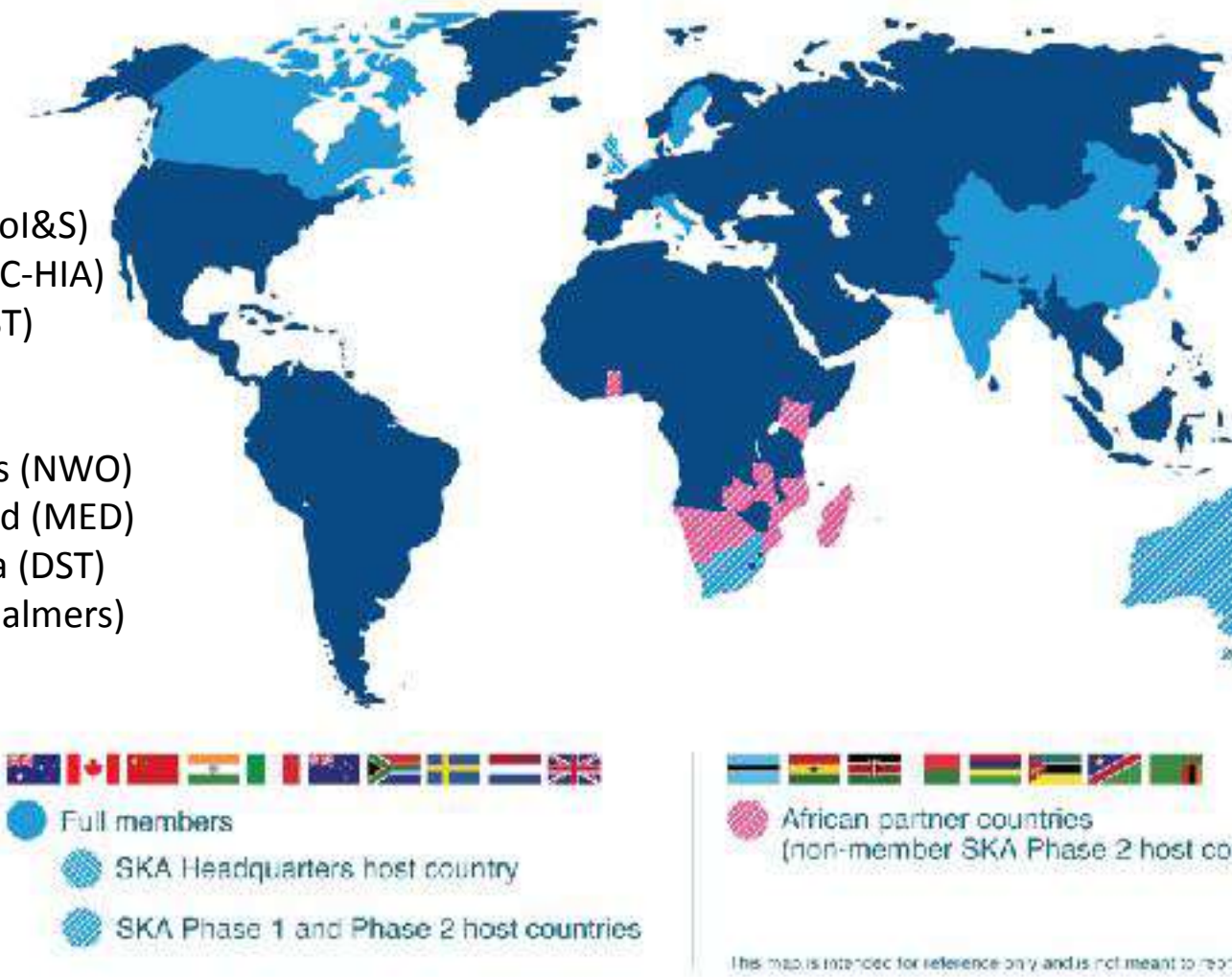
- Thirty-six 12 m antennas
- 30 deg² Field of View
- Frequency range 700 – 1800 MHz
- 6 km max baseline
- Tsys ~ 80 K

Credit: Alex Cherney/CSIRO

Getting on the SKA plane..

SKA Organisation: 10 countries, more to join

Australia (DoI&S)
Canada (NRC-HIA)
China (MOST)
India (DAE)
Italy (INAF)
Netherlands (NWO)
New Zealand (MED)
South Africa (DST)
Sweden (Chalmers)
UK (STFC)



Interested Countries:

- France
- Germany
- Japan
- Korea
- Malta
- Portugal
- Spain
- Switzerland
- USA

Contacts:

- Mexico
- Brazil
- Ireland
- Russia

The Exhausting Reality of SKA

The Exhausting Reality of SKA

The Exhausting Reality of SKA

The Exhausting Reality of SKA

The Exhausting Reality of SKA

The Exhausting Reality of SKA

The Exhausting Reality of SKA

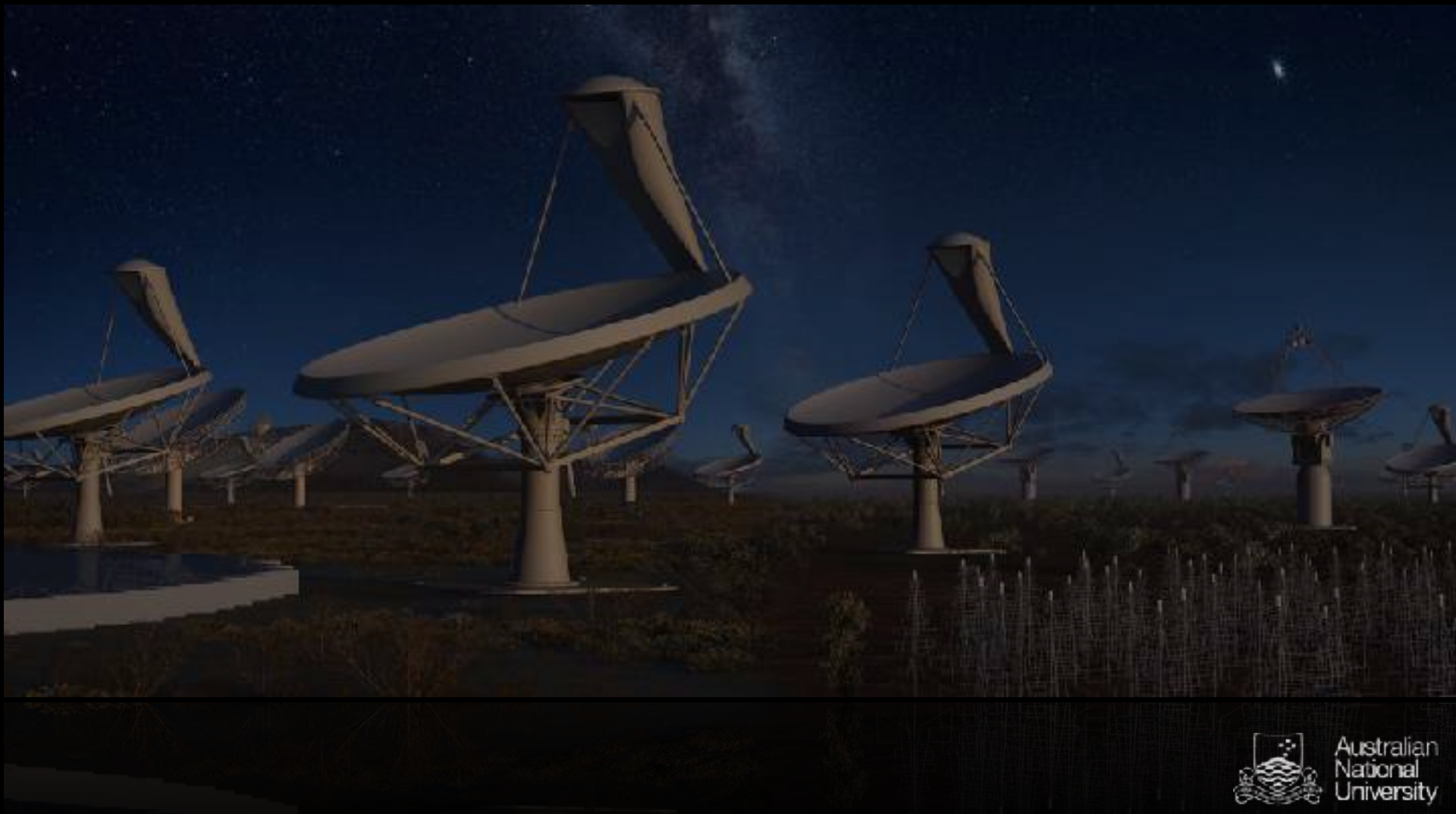
The Great Observatories

Credit: SPDO/TDP/DRAO/Swinburne Astronomy Productions.

Credit: C. Padilla, NRAO/AUI/NSF)

Credit: Todd Mason/Mason Productions and GMTO Inc.

SKA To Do:



Australian National University

SKA To Do:

- Design it…

SKA To Do:

- Design it…
- Build it…

Australian National University

SKA To Do:

- Design it…
- Build it…
- Use it!

Australian National University