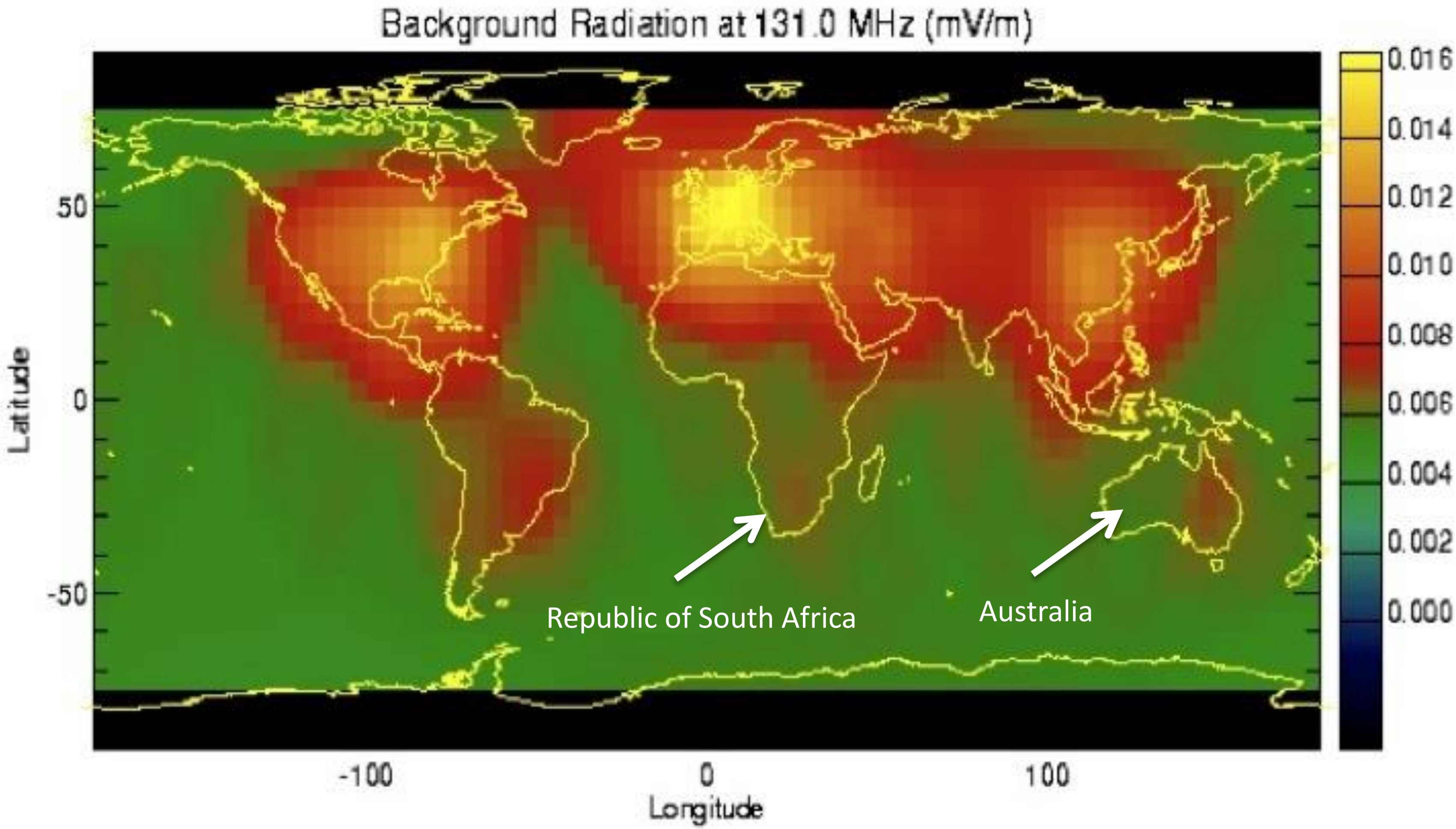
Square Kilometre Array: World's Largest Radio Telescope

Design and Science drivers

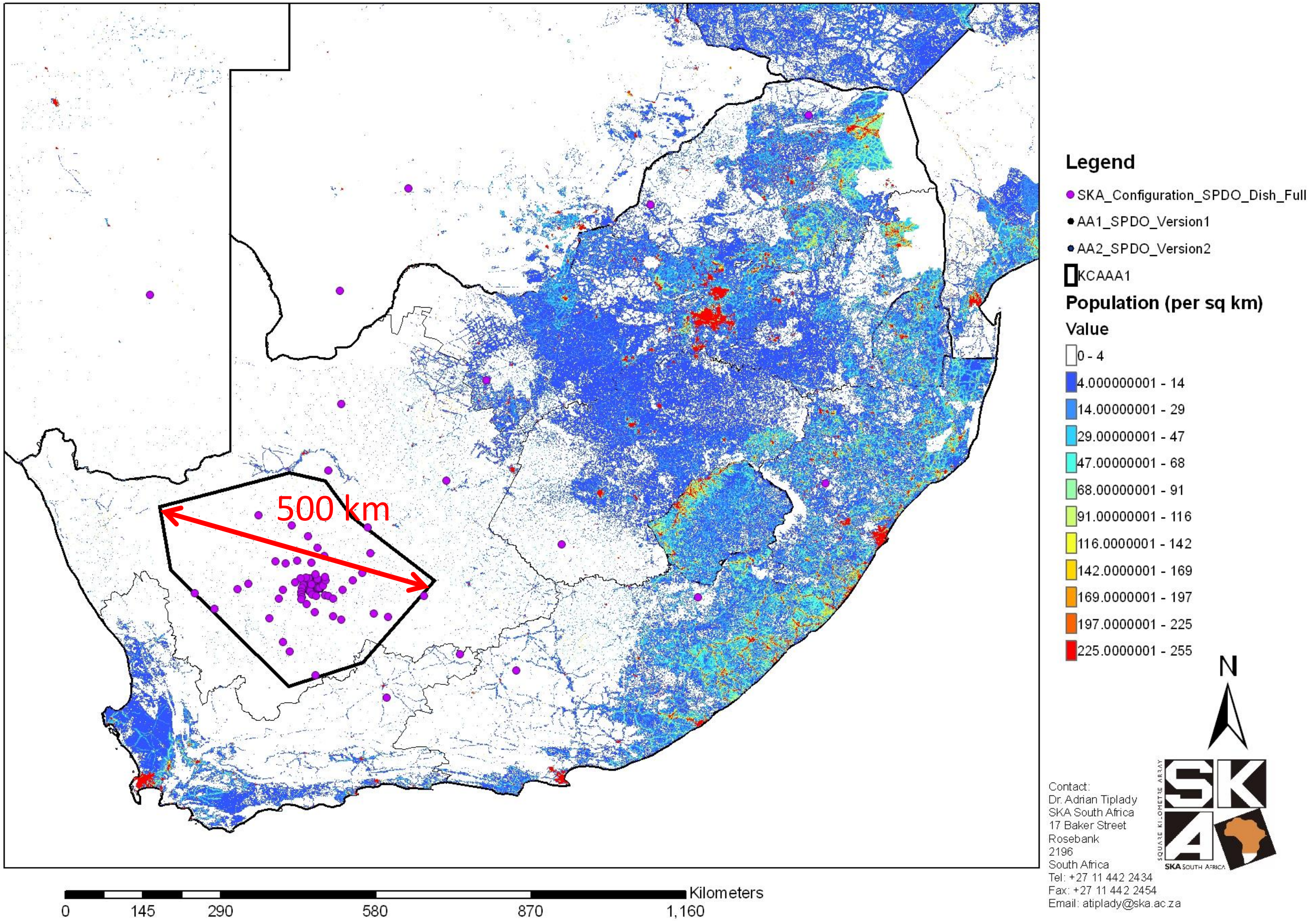
Miroslava Dessauges
Geneva Observatory, University of Geneva

With my thanks to Philip Diamond (SKA director-general),
Tyler Bourke (SKA organisation), Jeff Wagg (SKA project scientist)

SKA site selection



Karoo Radio Astronomy Reserve



Exploring the Universe with the World's largest telescope

Murchison Radio Astronomy Observatory

Shire of Murchison:

- 50,000 km²
- 0 gazetted towns
- 29 sheep/cattle stations
- 110 population => 0.002 km^{-2}

SKA specifications

SQUARE KILOMETRE ARRAY

Greatest Observatory for the coming decades

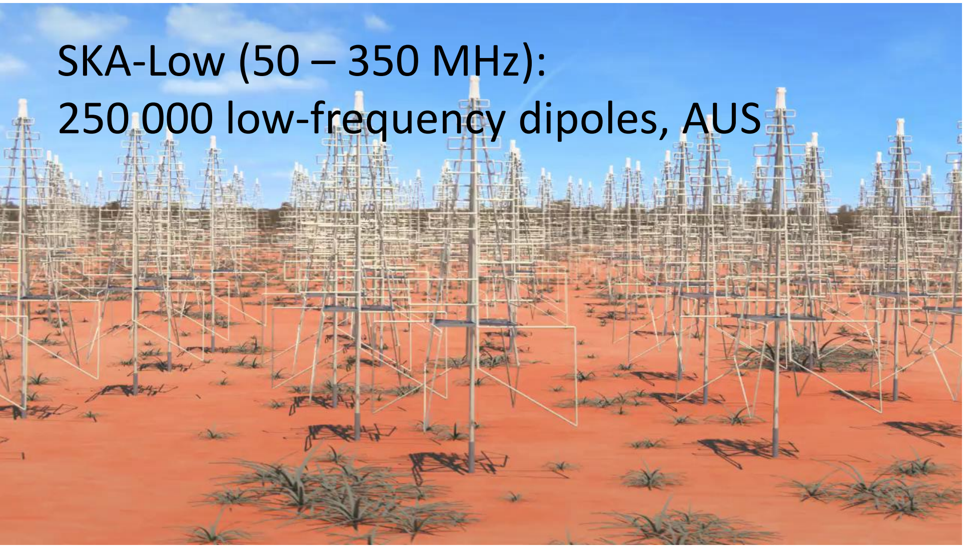
2 sites; 3 telescopes; one Observatory

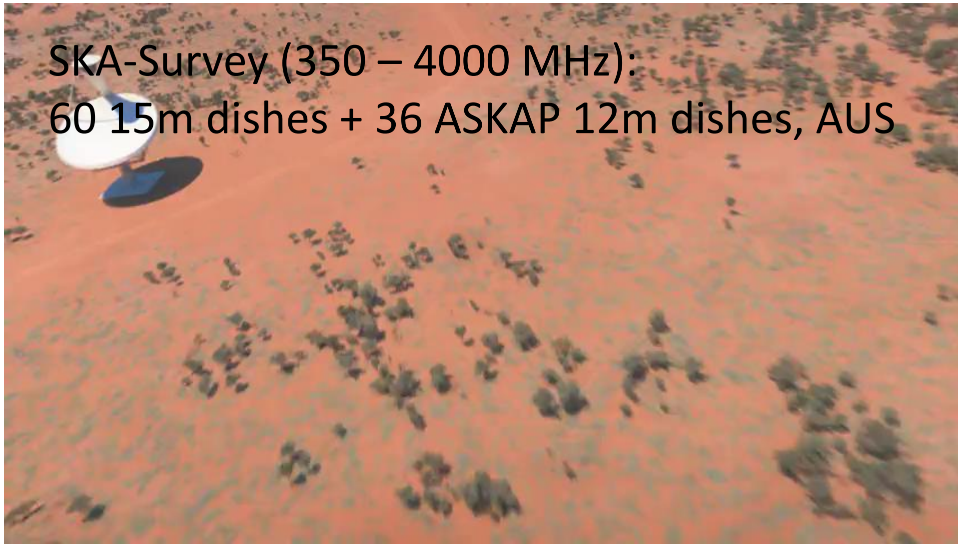
Frequency range: Phase 1 –> 50 MHz – 3 GHz
Phase 2 –> up to 15 GHz

Cost-cap: €650M

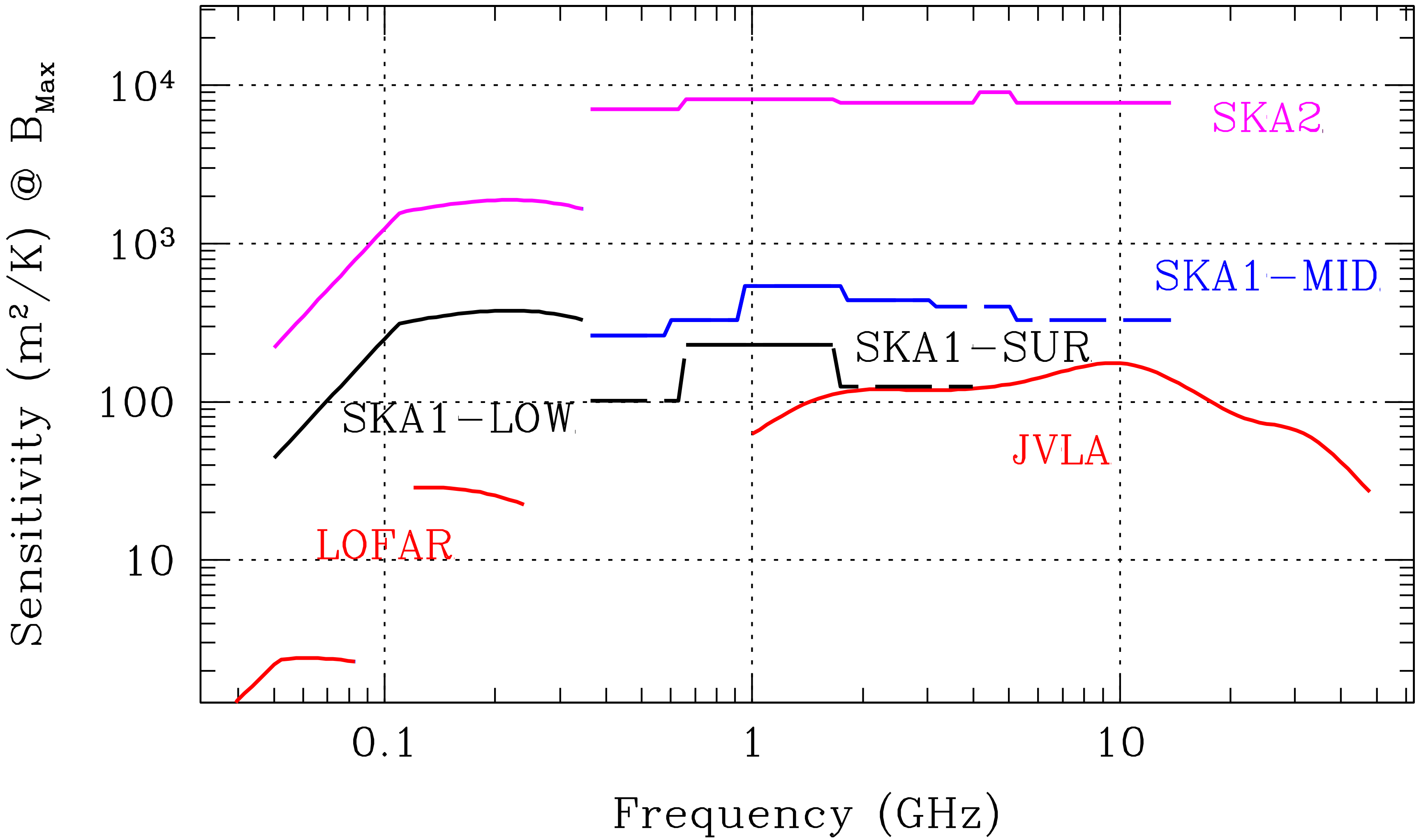
Construction for Phase 1: 2017 – 2023

Early science for Phase 1: 2020

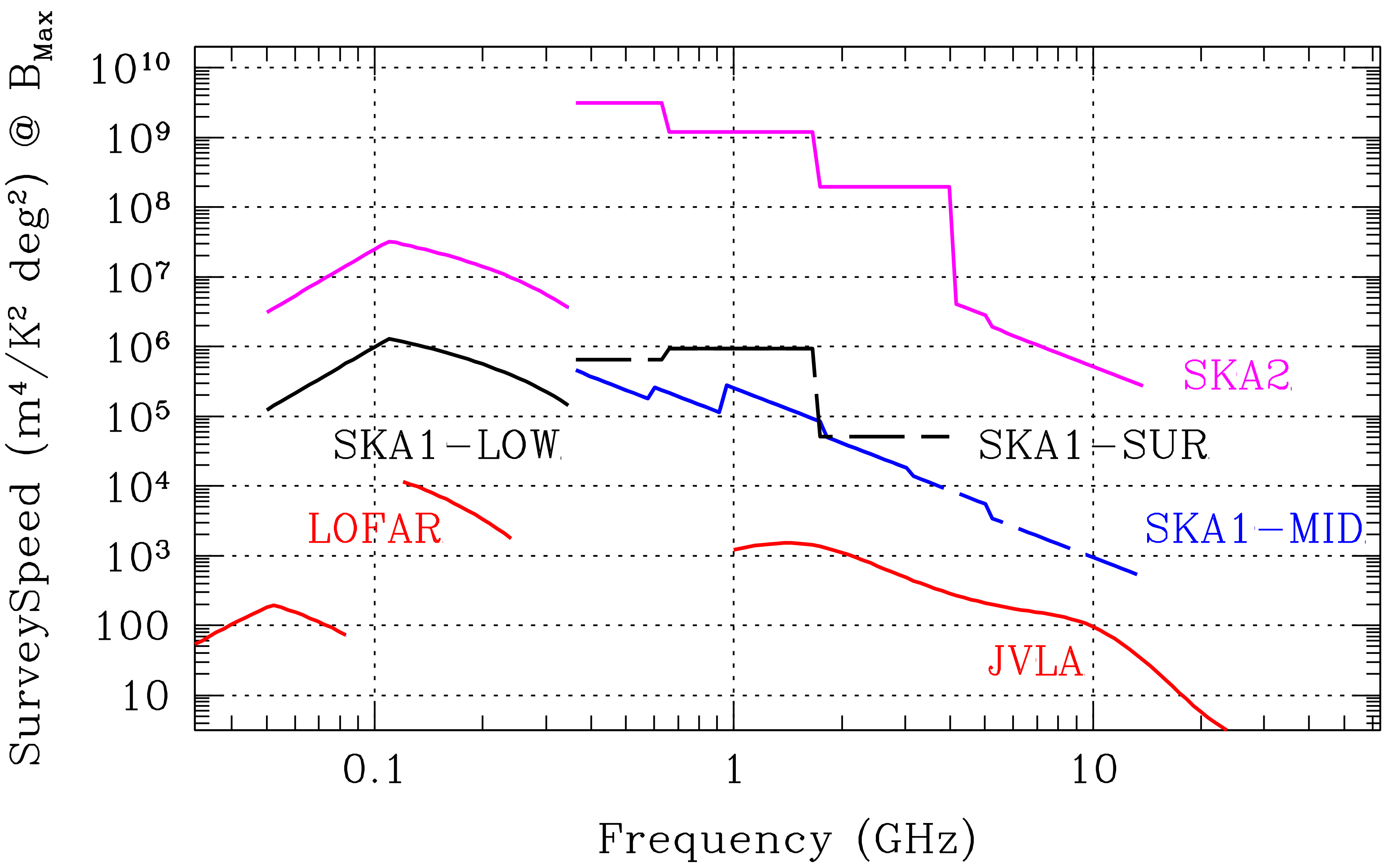




Sensitivity comparison

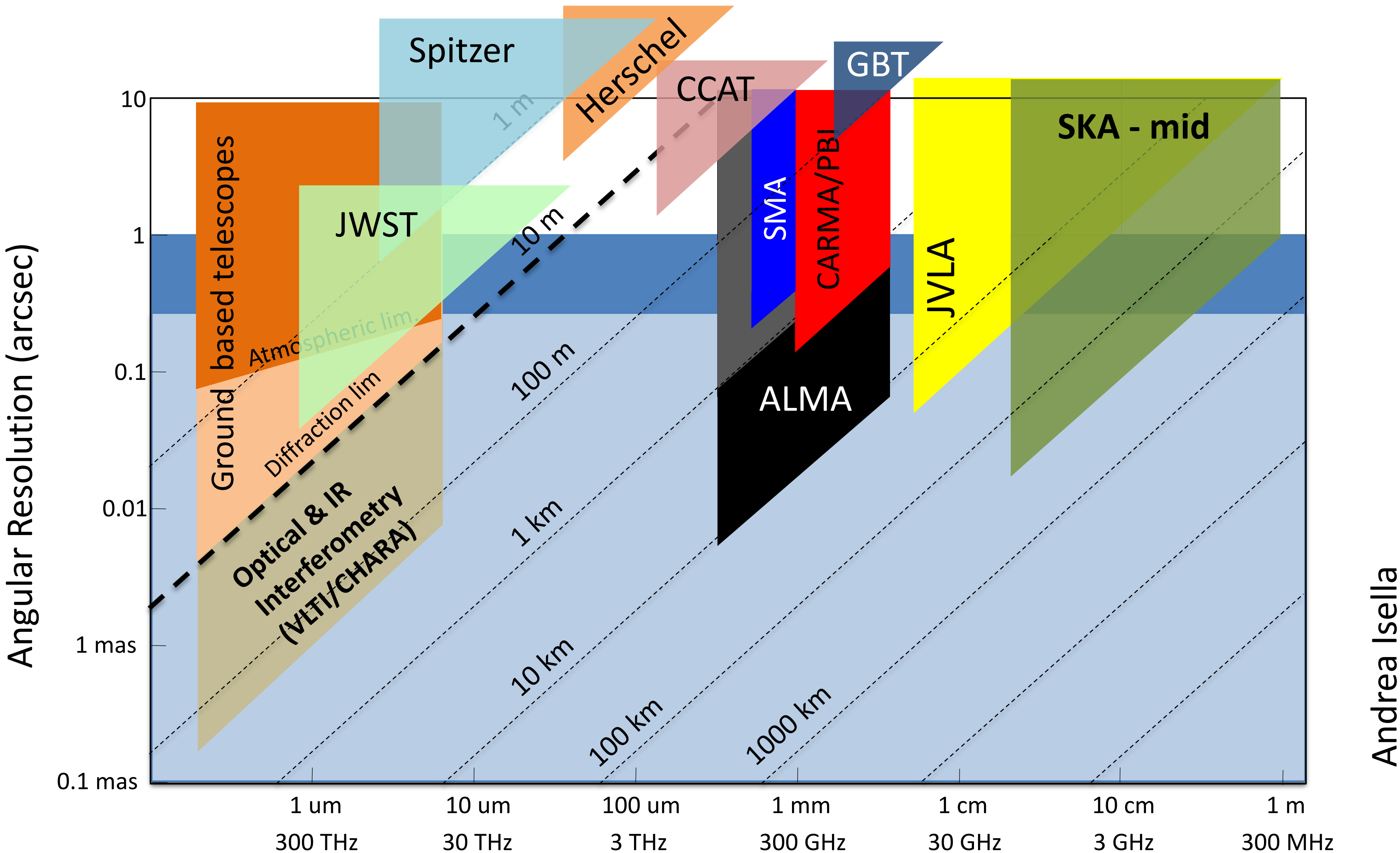


Survey speed comparison



Exploring the Universe with the World's largest telescope

Angular resolution comparison



Emerging themes for 21st century astrophysics

20th Century: We discovered our place in the Universe

21st Century: We understand the Universe we inhabit

Remaining major enigma – SKA science drivers:

Fundamental Forces and Particles

- Gravity
  - Radio pulsar tests of General Relativity
  - Gravitational Waves
  - Dark Energy
- Magnetism
  - Origin and evolution of Cosmic Magnetism

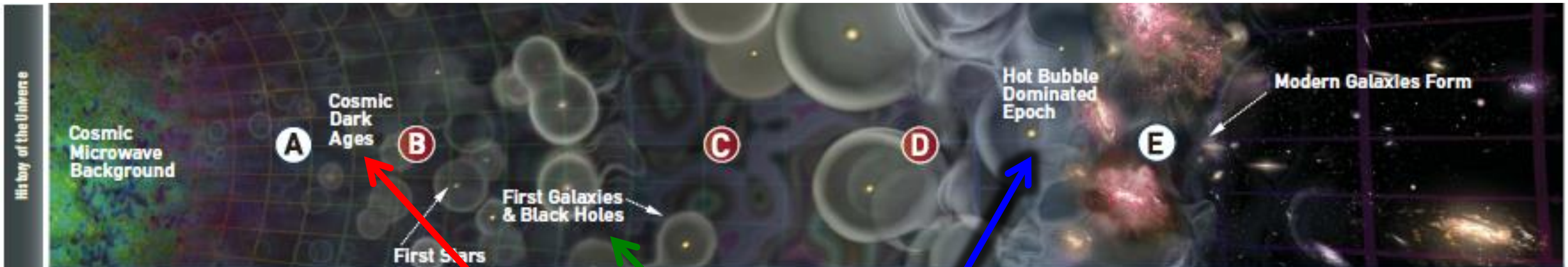
Cosmic Origins

- Galaxies and the Universe
  - Cosmic Dawn, Epoch of Reionization
  - First Galaxies
  - Galaxy Assembly and Evolution
- Stars, Planets, and Life
  - Protoplanetary disks
  - Biomolecules
  - SETI

➔ SKA is a Physics Machine

Cosmic Origins

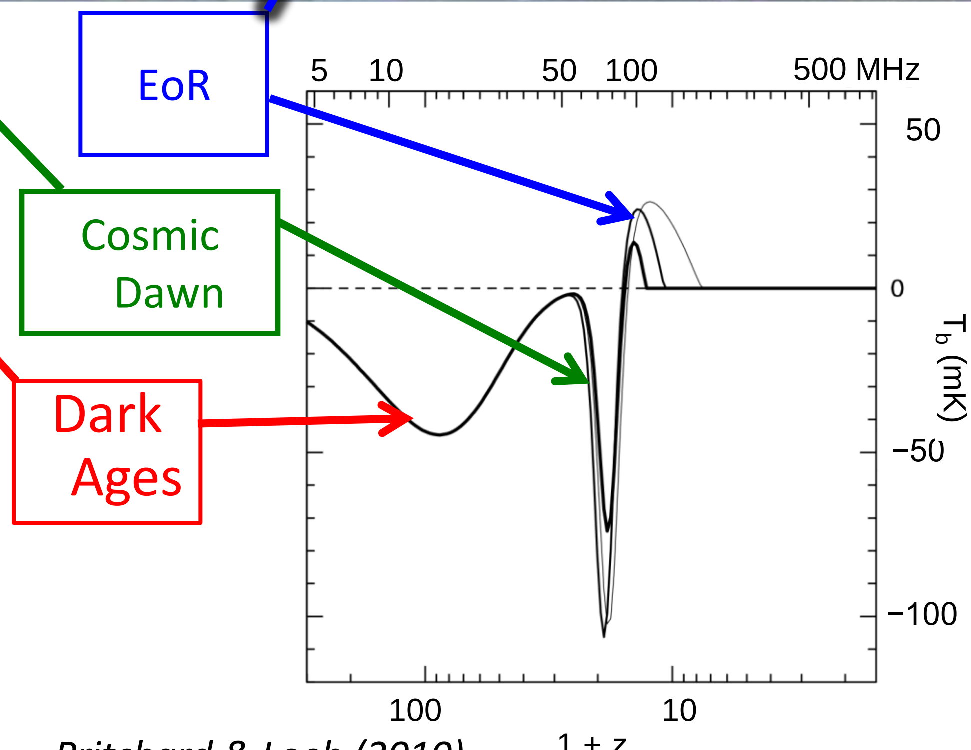
Probing the early Universe with the 21 cm HI line



Neutral Hydrogen

21 cm spin-flip transition provides probe of neutral intergalactic medium before and during formation of first stars/galaxies

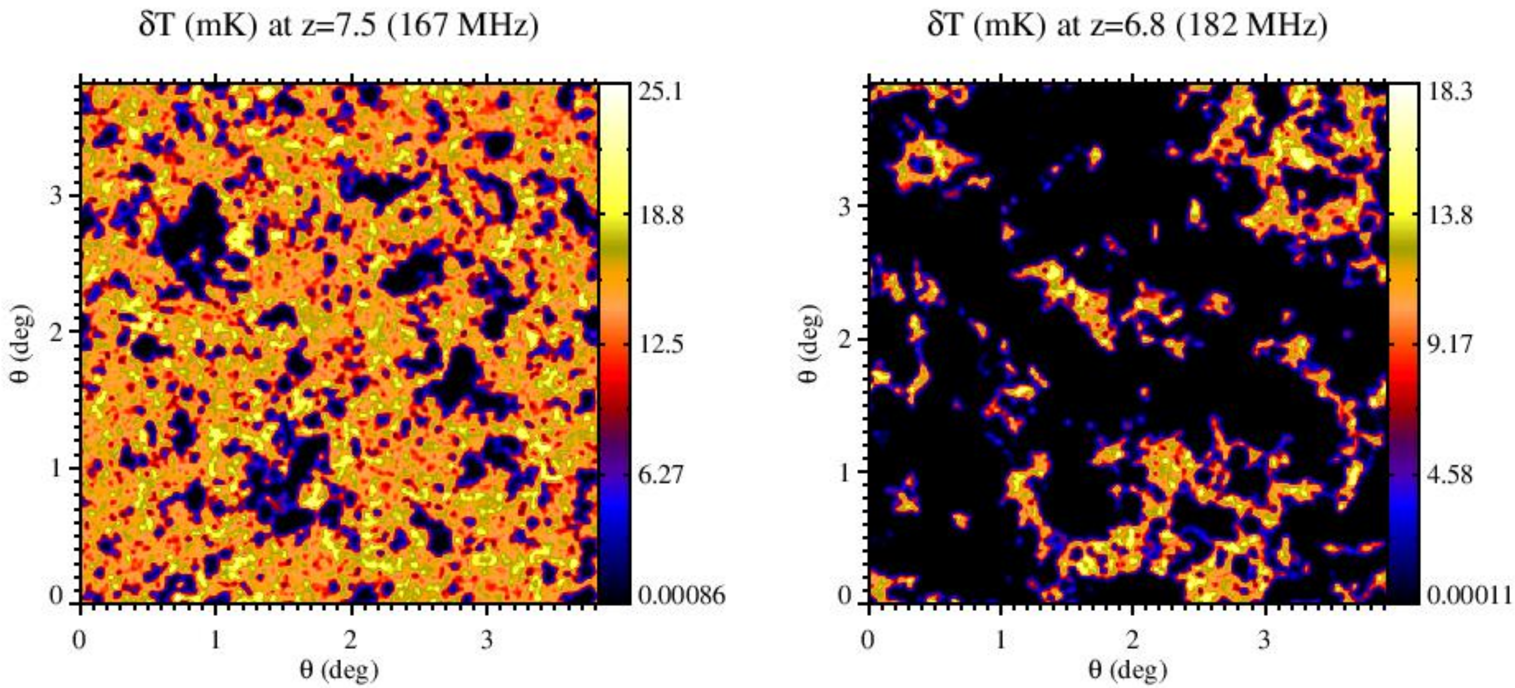
$$\nu = 1420\ \mathrm{MHz}/(1 + z)$$
$$\lambda = 21\ \mathrm{cm}\ (1 + z)$$



Pritchard & Loeb (2010)

HI surveys of the Cosmic Dawn and the Epoch of Reionization (EoR)

Review by Mellema et al. (2013)

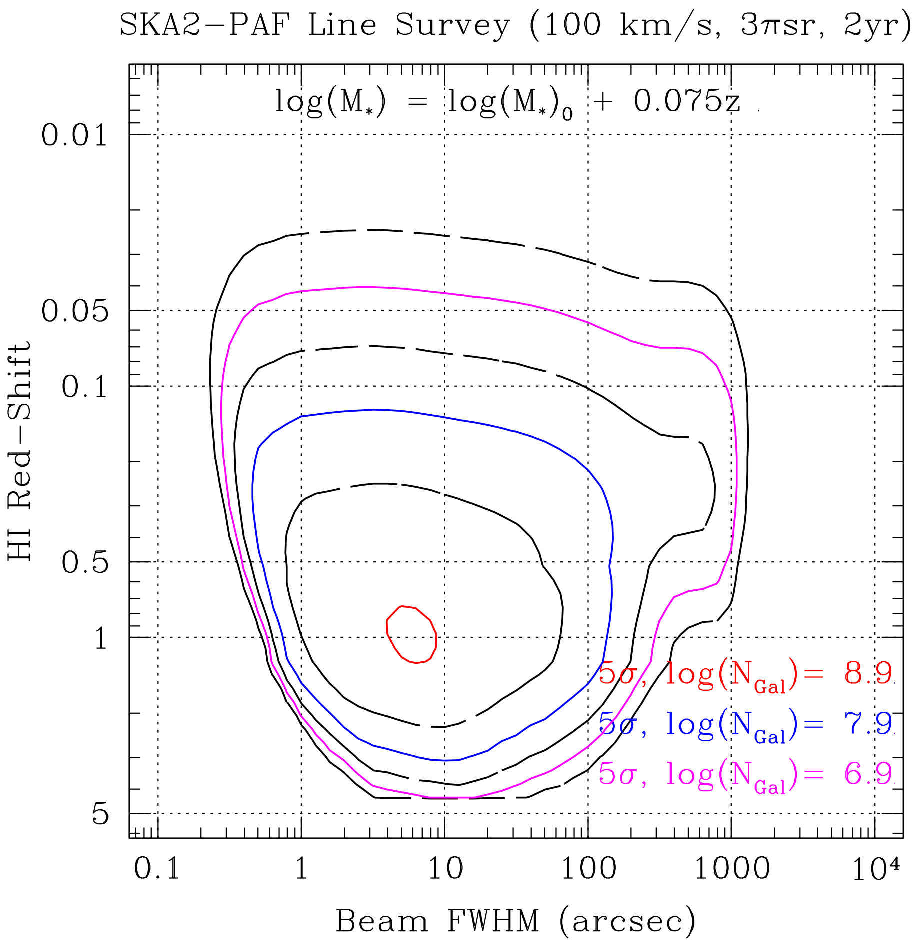


– Tomography to $\delta T = 1$ mK level on a few arcmin scales, required to map out HI temperature fluctuations in the IGM over cosmic time during the Cosmic Dawn and Epoch of Reionization

– Tomography to $\delta T = 10$ mK level over many arcmin scales, required to map out ionized bubbles during the Epoch of Reionization

Studying the cosmic reionization using SKA will give new insights on both the nature of the primordial sources and the 3-D maps of HI distribution during the entire epoch of cosmic dawn and reionization at redshifts $6 < z < 27$.

The billion galaxy survey through HI emission



HI galaxy counts

Duffy et al. (2012)
semi-analytic + N-body simulations

- $10^{8.9}$ galaxies with $\langle z \rangle \approx 1$
- $10^{7.9}$ galaxies with $\langle z \rangle \approx 2$

–> redshift surveys
–> large scale structures up to z ~ 5
–> HI mass density cosmic evolution $\Omega_{HI}(z)$
–> galaxy kinematics = dynamical masses

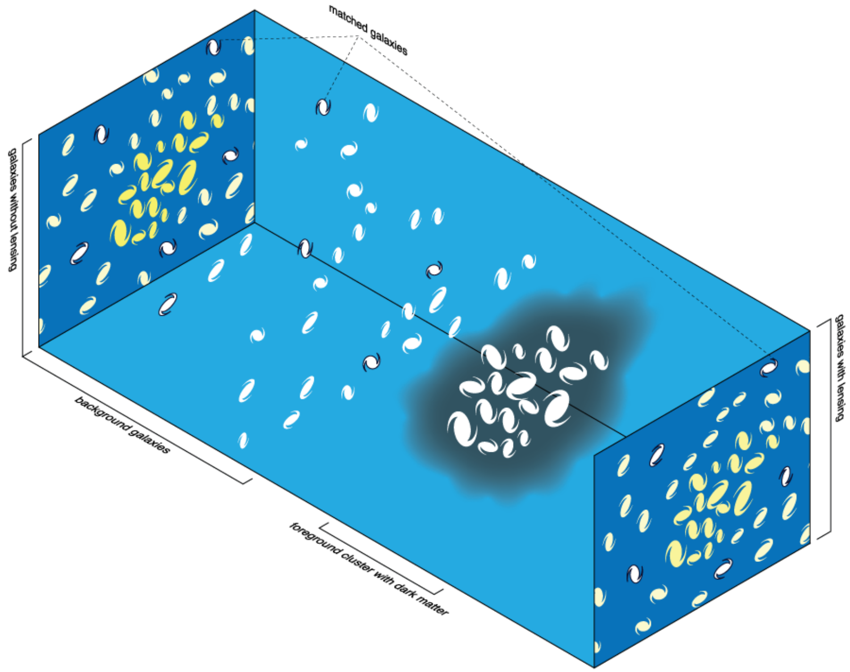
–> precision cosmology

Fundamental Forces and Particles

Dark Energy equation of state

Universe's composition:

5% of Baryonic Matter
27% of Dark Matter (unknown nature)
68% of Dark Energy (unknown nature)



The Universe is accelerating:

Dark Energy must counteract/surpass the gravi
and Dark Matter. The rate and speed of the forı
due to the balance between gravitational attra
Energy. The measure of this rate and speed is a n

Constraining Dark Energy equation of state with:

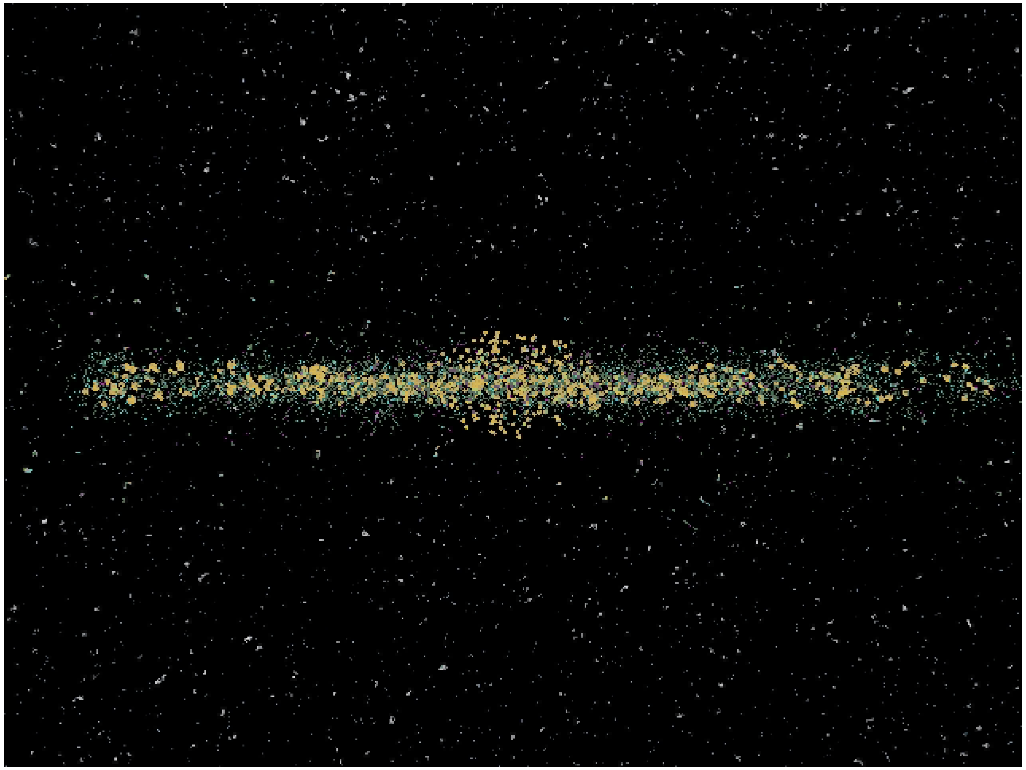
1. redshift-resolved Baryon Acoustic Oscillation measurements at different z

   previous surveys: SDSS $10^{6.2}$ galaxies with <z> ≈ 0.1; BOSS $10^{5.4}$ galaxies with <z> ≈ 0.57; WigglesZ $10^{5.2}$ galaxies with <z> ≈ 0.6

2. weak gravitational lensing measurements of cosmic shear

Systematic survey for pulsars in the Milky Way

Cordes et al. (2004); Kramer et al. (2004); Smits et al. (2008)



Objective

~ 30 000 normal pulsars

~ 100 relativistic binaries

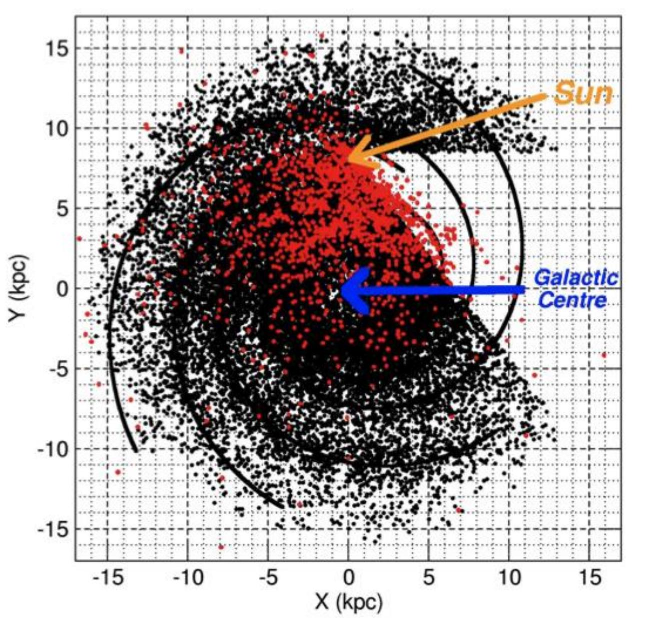
first pulsars in Galactic Centre

first extragalactic pulsars

- Timing precision is expected to increase by factor ~100
- Rare and exotic pulsars and binary systems: including PSR-BH systems!
- **Current estimates are that ~50% of entire Galactic population in reach of SKA**

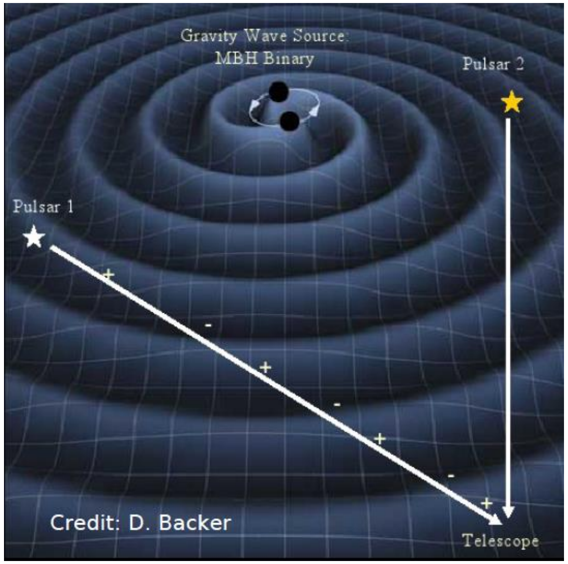
Tests of gravity in strong gravitational fields

Test General Relativity in strong field regime



Tests of GR in strong field regime via:
Neutron Star – White Dwarf binaries
Neutron Star – Neutron Star binaries
Neutron Star – Black Hole binaries

Direct detection of gravitational waves



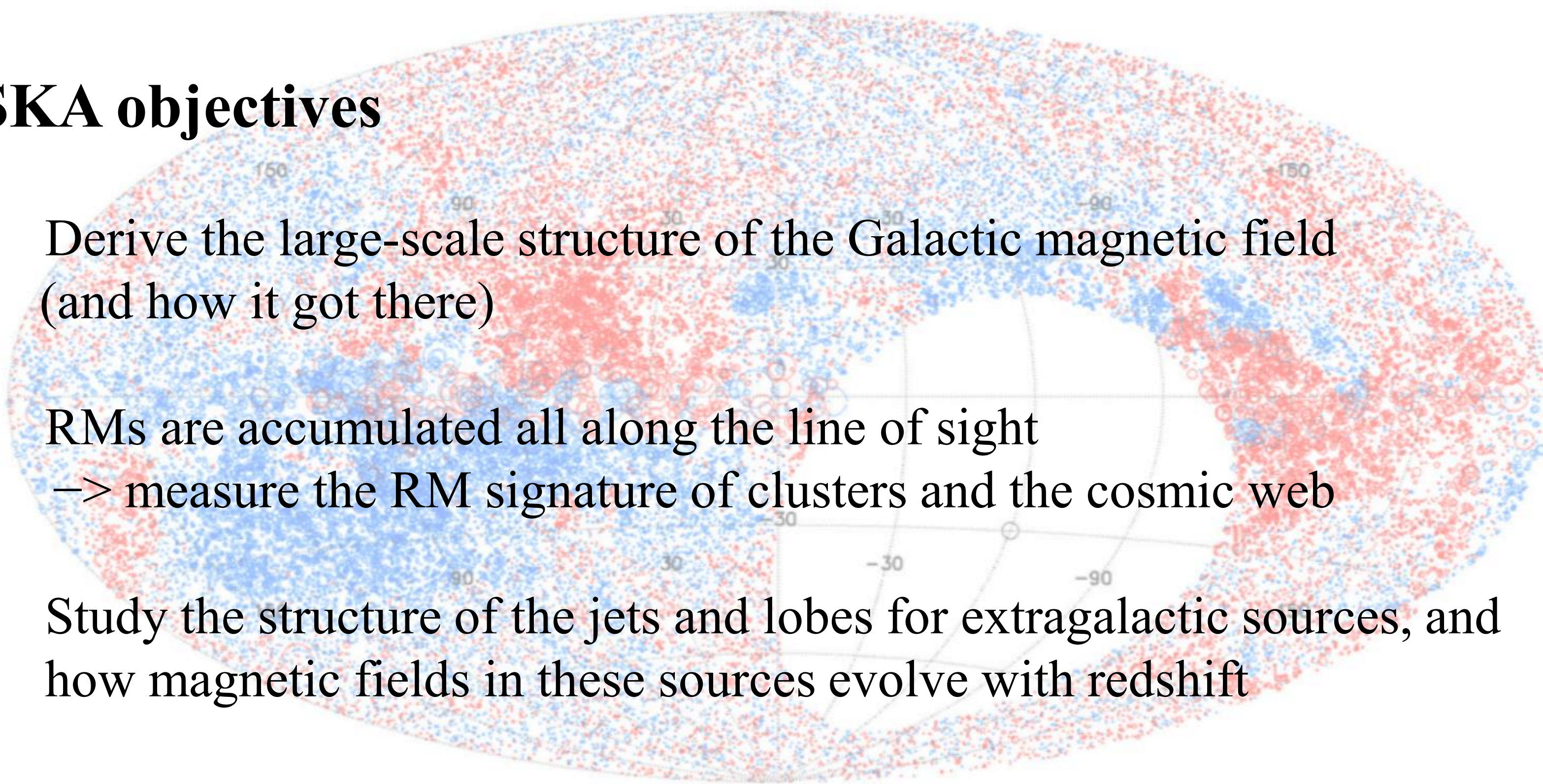
Pulsar arrival times affected by low-frequency gravitational waves correlated across the sky

In a Pulsar Timing Array (PTA) pulsars act as arms of a cosmic GW detector

Sensitive to nHz waves, complementary to LIGO/LISA

Cosmic magnetism: rotation measure grid

Access to galactic magnetic fields through the measure of the Faraday Rotation induced on the polarization vector of radio waves propagating through magnetized plasma.



SKA objectives

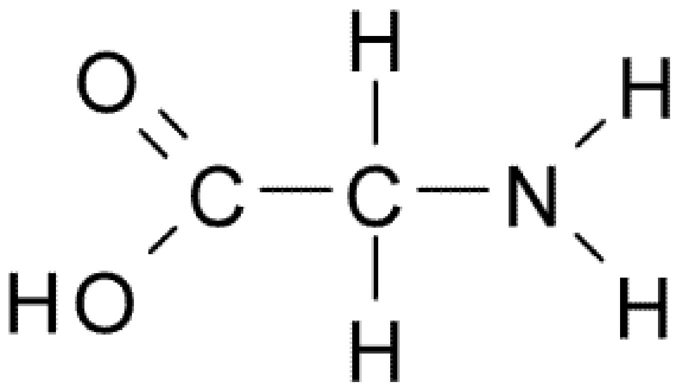
- Derive the large-scale structure of the Galactic magnetic field (and how it got there)
- RMs are accumulated all along the line of sight
  –> measure the RM signature of clusters and the cosmic web
- Study the structure of the jets and lobes for extragalactic sources, and how magnetic fields in these sources evolve with redshift

Cradle of life

Glycine NH_2CH_2COOH

Holy grail of prebiotic astrochemistry

detection of an amino acid in the gas phase



Firm detections in meteorites and comets
((*Ehrenfreundet al. 2001*; *Elsila et al. 2009*)

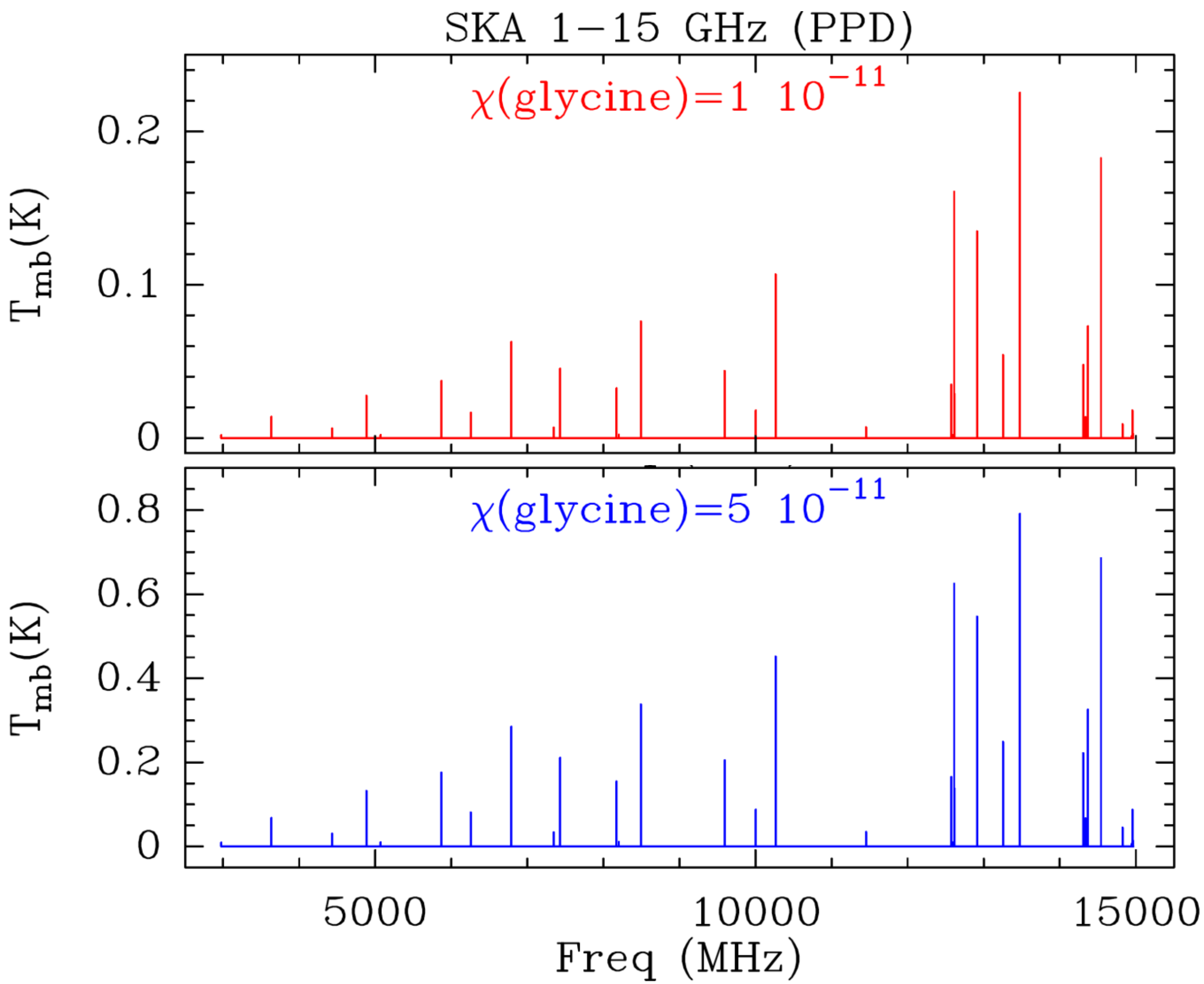
Not (yet) detected in the ISM

Cold cores and disks – frozen onto dust grains?

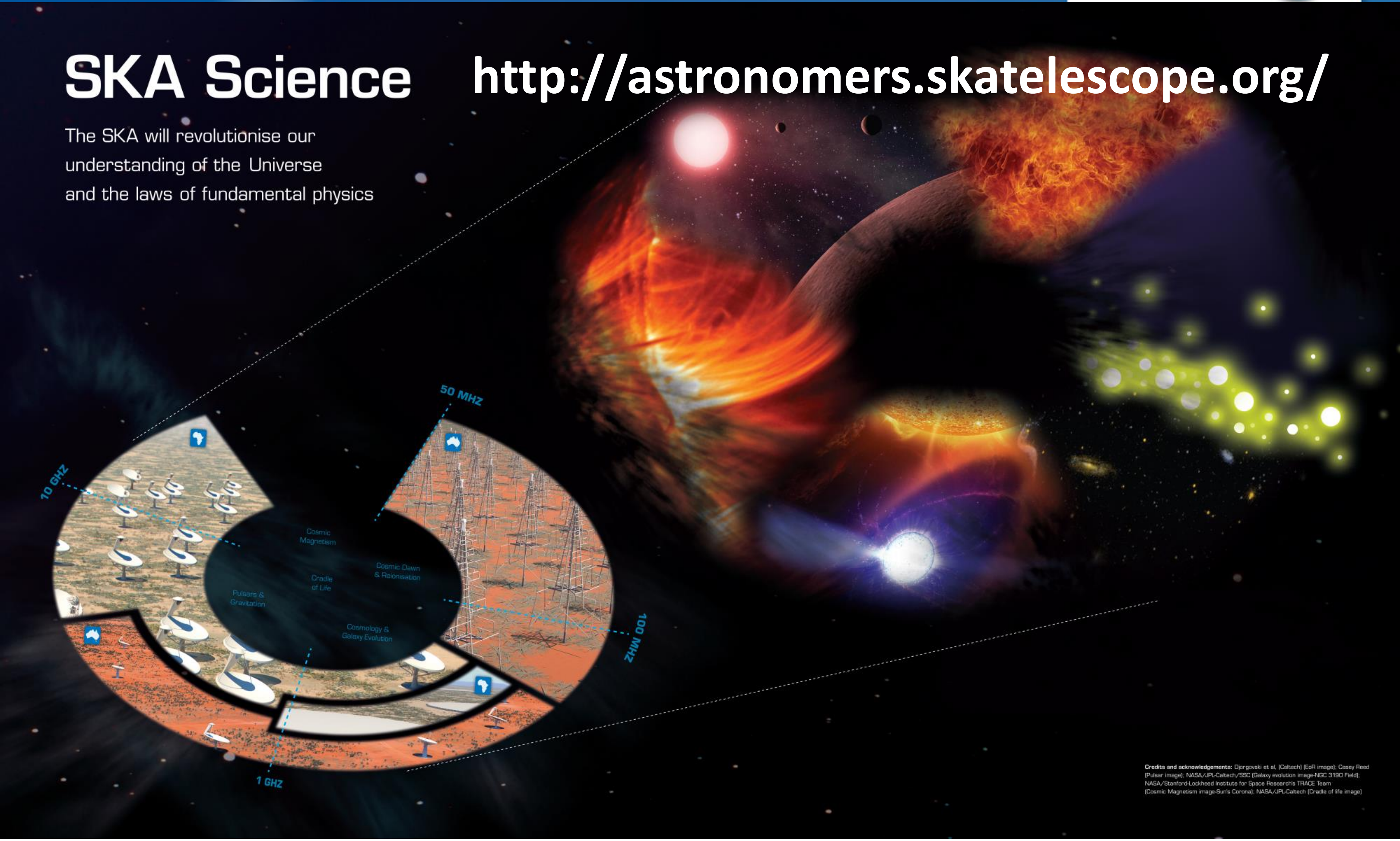
Cradle of life
Glycine NH_2CH_2COOH

SKA simulations of the Glycine observations:

Glycine lines detected with S/N > 3 in 8 hours with SKA1-MID (model dependent!)

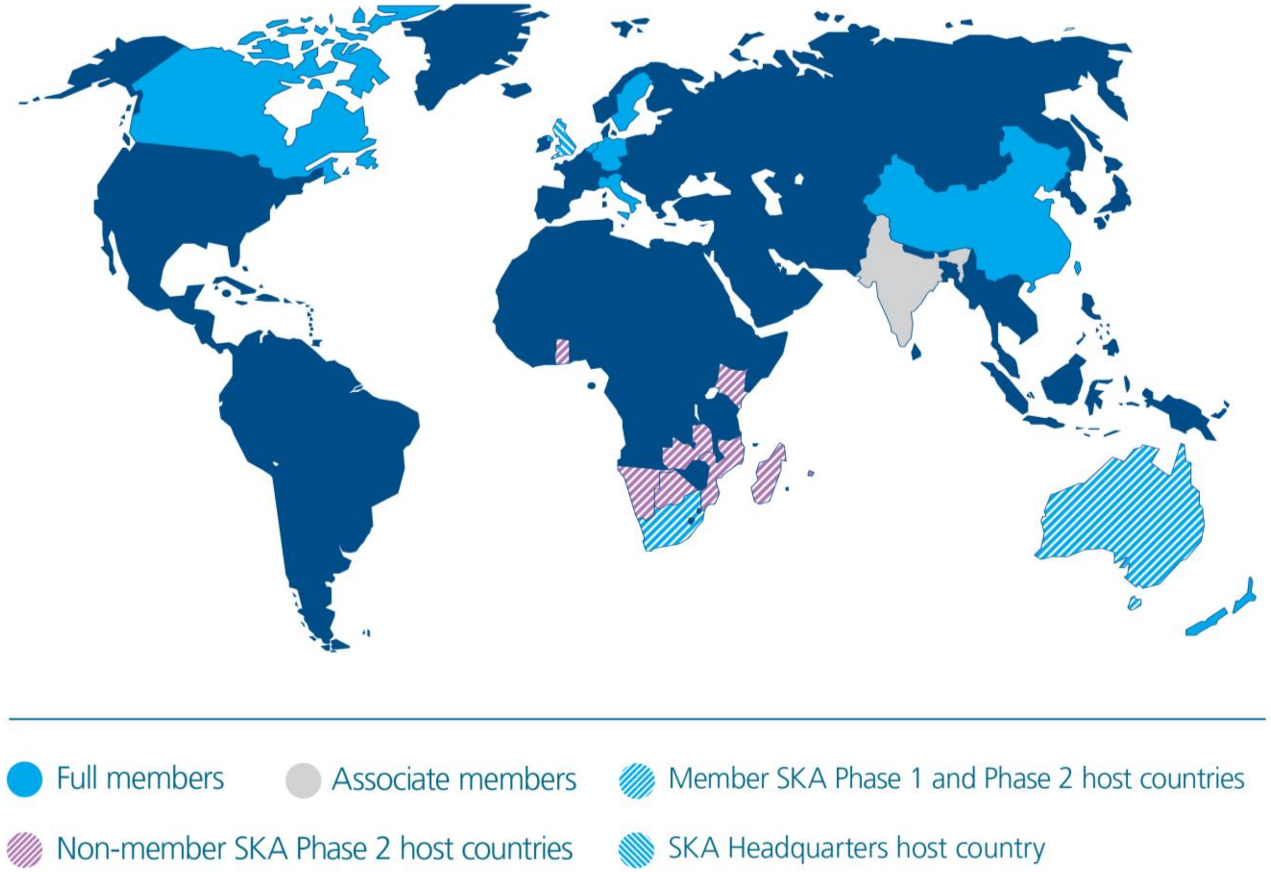


More SKA science



SKA members

Australia
Canada
China
Germany
Italy
Netherlands
New Zealand
South Africa
Sweden
UK
India



Others? Spain, Portugal, Japan, Brasil all interested. USA, but no money.

1M Euros buy in, plus % contributions based on GDP

SKA and Switzerland ?

Astronomers from UniGe, EPFL, and ETHZ have coordinated to reply to

"*the Call for Applications for New Research Infrastructures of National Relevance*"

of January 2014 with the aim to be involved and contribute in the SKA project to the level of at least **50M Euros** scattered over more than a decade.

An Answer to the Call for Applications for New Research Infrastructures of National Relevance

Understanding the Universe from Planets to Distant Galaxies with the Square Kilometer Array (SKA) Radio Telescope

Prof. D. Schaerer (UniGE), Prof. G. Meylan (EPFL), Prof. R. Teyssier (UniZH)

Abstract: **We propose a significant and key positioning of Switzerland, through technological and scientific participations, in the revolutionary international program Square Kilometer Array (SKA) devoted to interferometric observation at radio wavelengths of the nearby and distant Universe, using a few thousands antennas located in Australia and South Africa.**

SKA in a nutshell