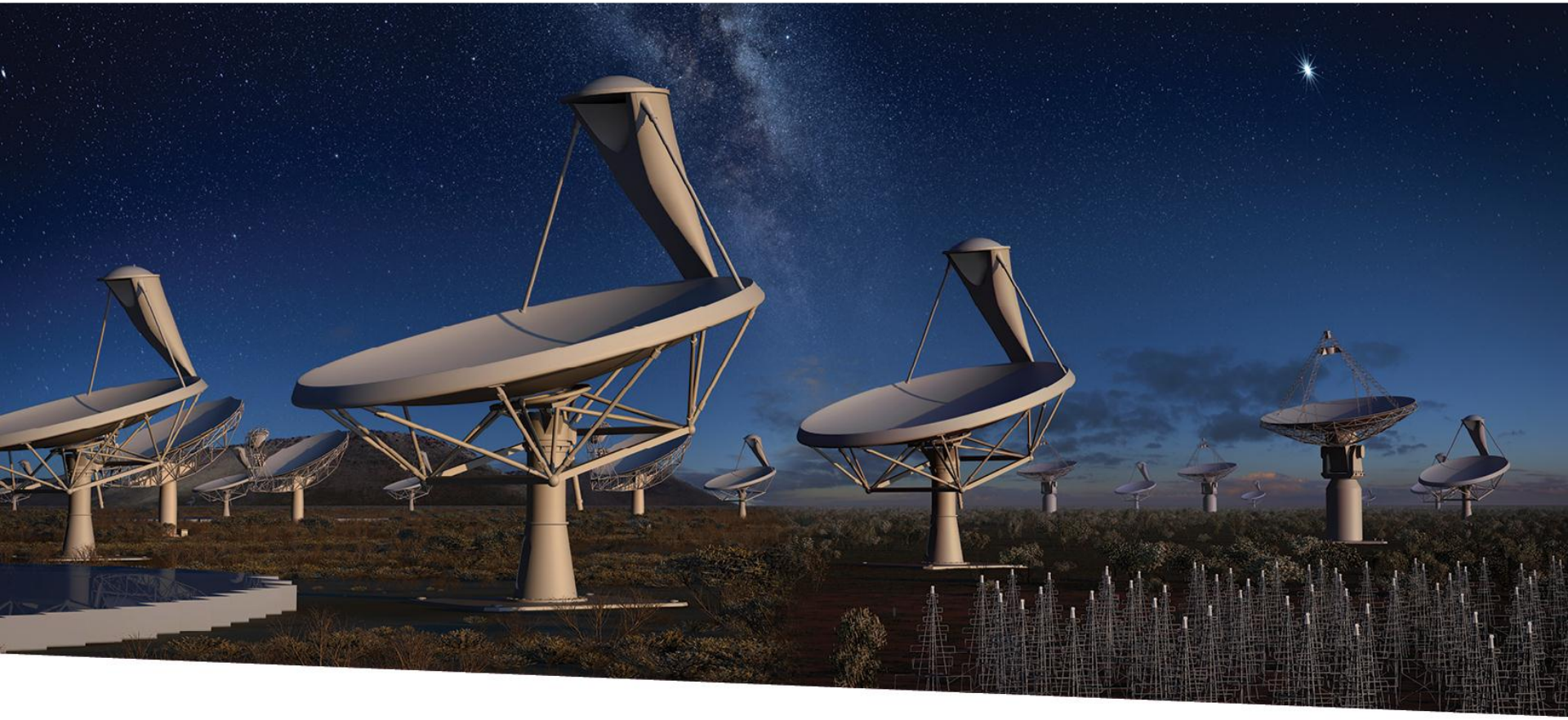
SKA Update and Science Prospects



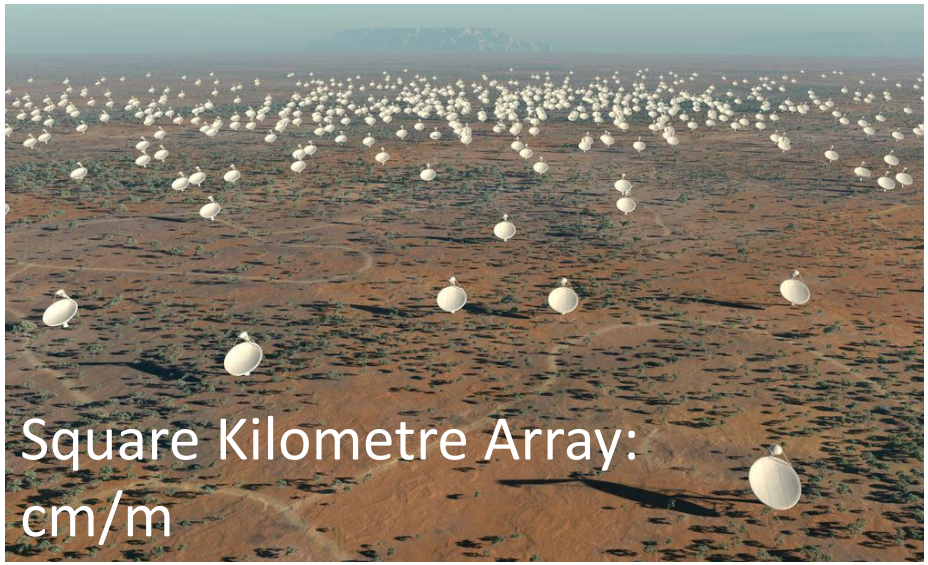
SQUARE KILOMETRE ARRAY

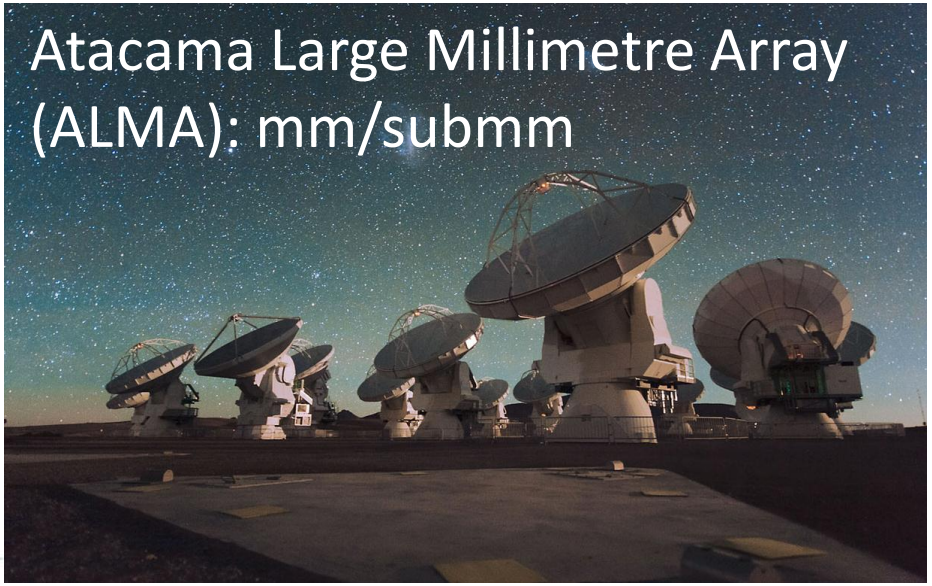
Exploring the Universe with the world's largest radio telescope

Robert Braun

20 January 2015

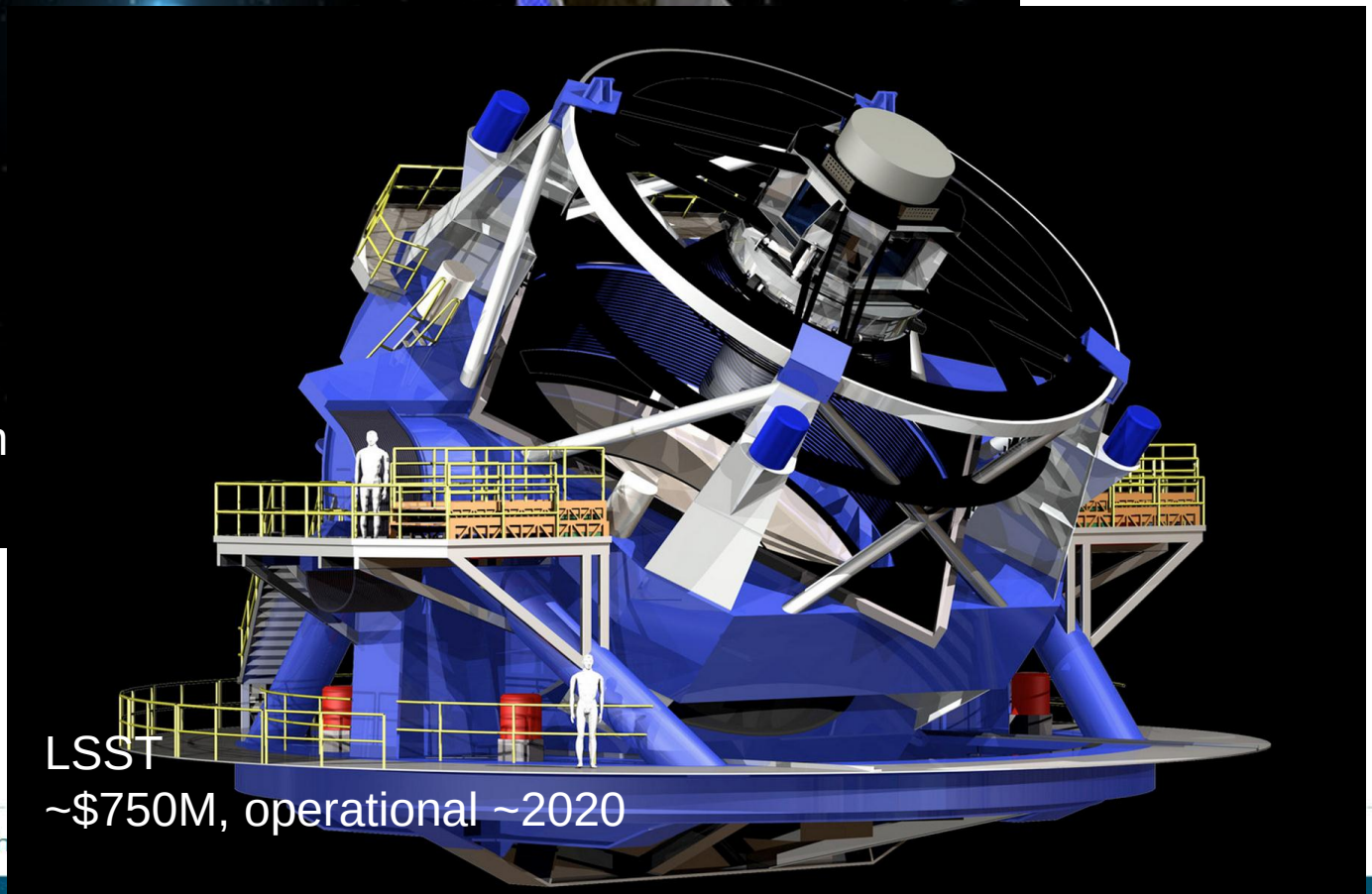
Great Observatories for the coming decades





More specialised “experiments”

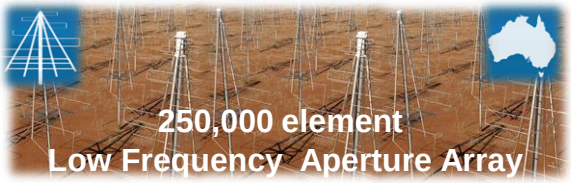
EUCLID:
~€1B, laun

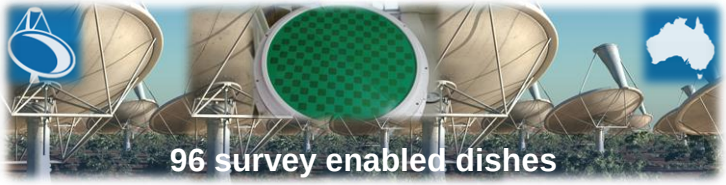


LSST
~$750M, operational ~2020

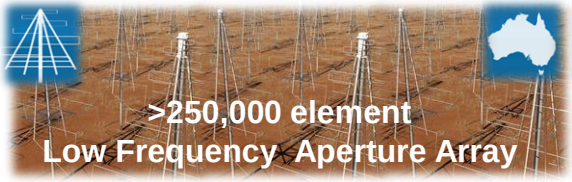
What is the SKA?

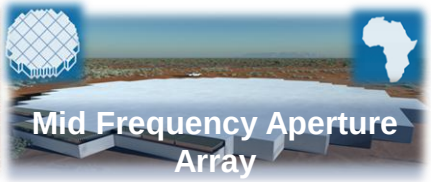
Phase I : 2020



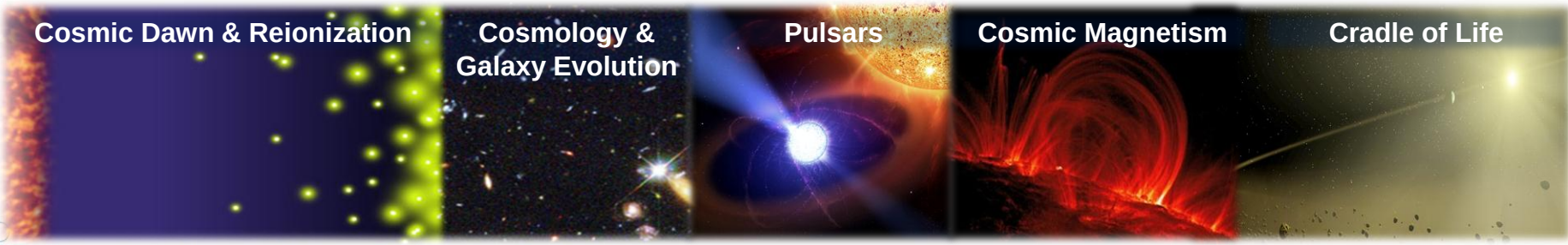


Phase II : 2024





Science

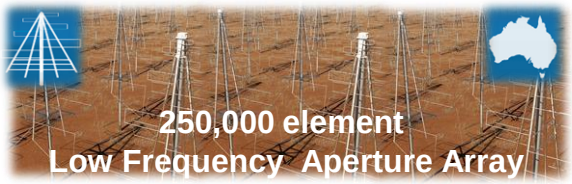


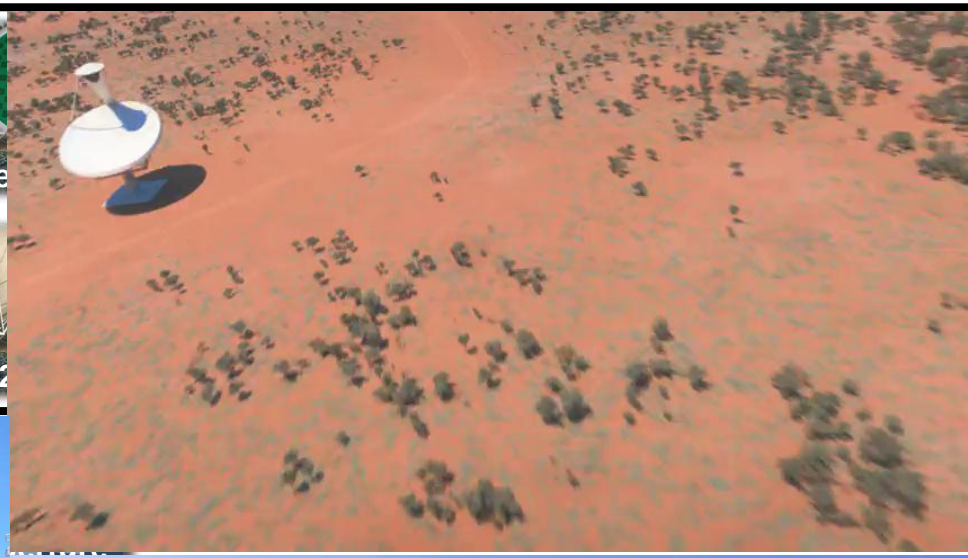
Exploring the Universe with the world's largest radio telescope

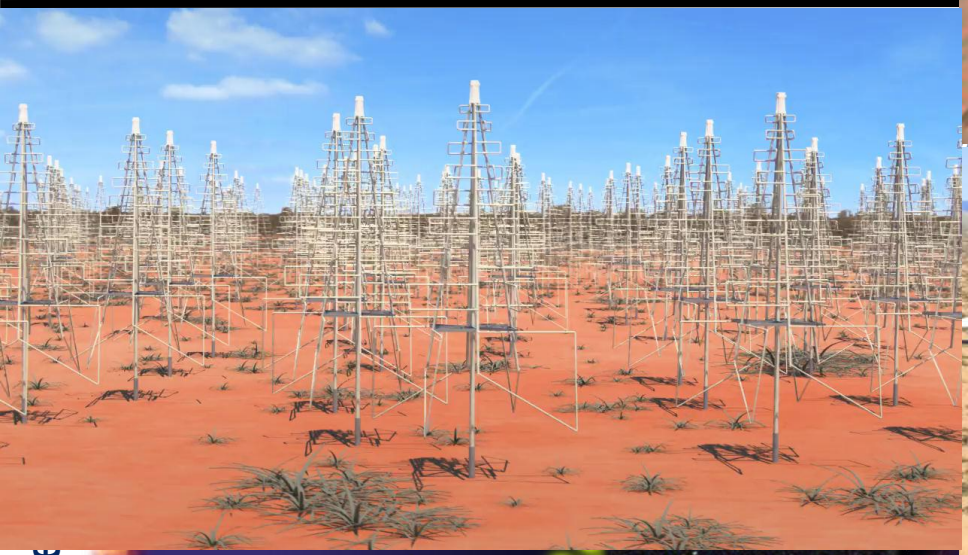
50 MHz 100 MHz 1 GHz 10 GHz

What is the SKA?

Phase I : 2020







Scie

Exploring the Universe with the world's largest radio telescope

50 MHz 100 MHz 1 GHz 10 GHz

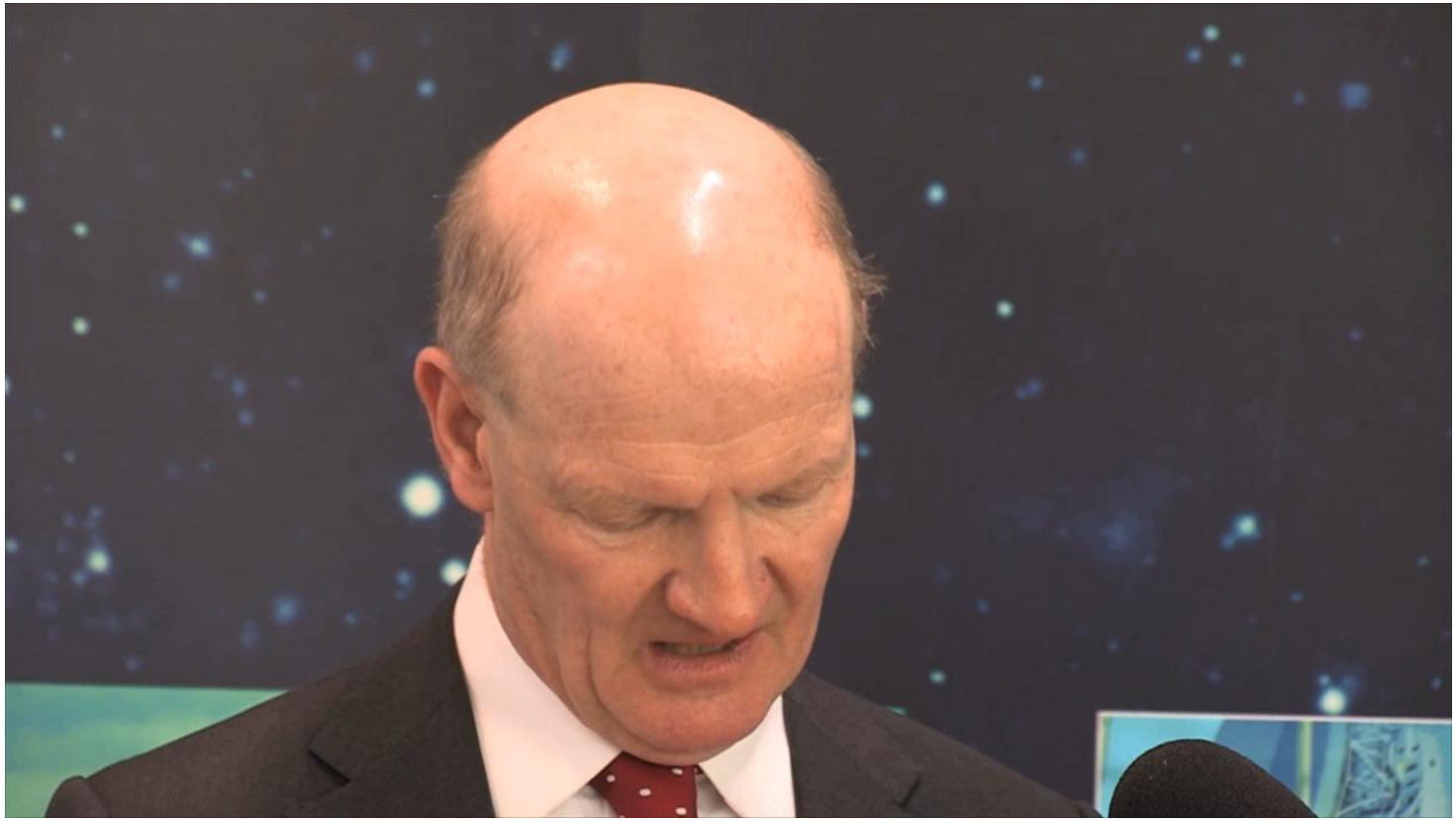
SKA Members and Governance

Australia (DoI)
China (MOST)
Italy (INAF)
New Zealand (MED)
Sweden (Chalmers)
India (Tata/DAE)

Canada (NRC-Herzberg)
Germany (BMBF)
Netherlands (NWO)
South Africa (DST)
UK (STFC)

- UK Company Limited by Guarantee
- Expedient solution to enable SKA project to proceed; long-term governance structure under review – studying establishing a treaty organisation.

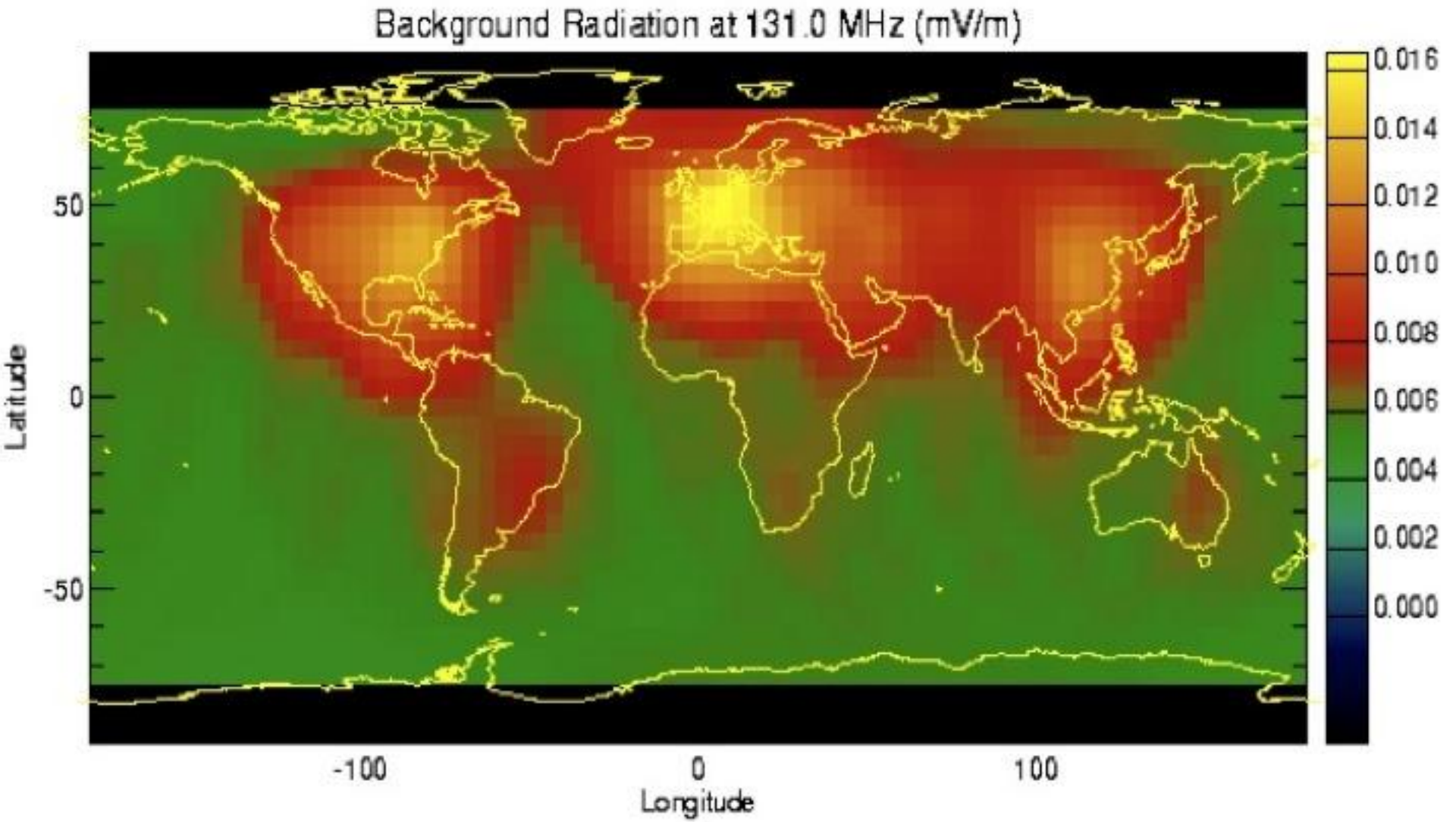
Excellent start to 2014



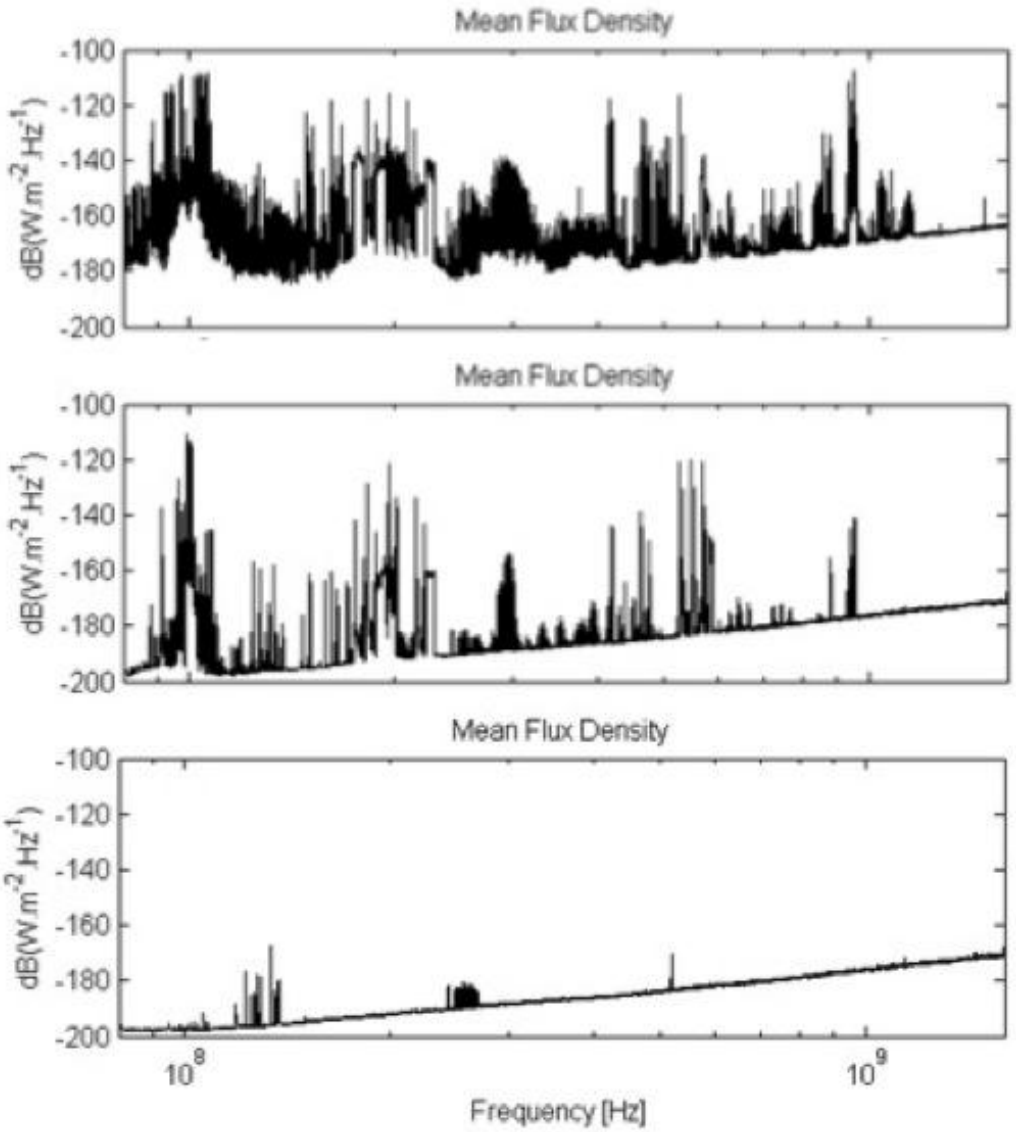
£100M commitment from UK

- 15% contribution to construction and early operations

How did we choose the sites?



How did we choose the sites?

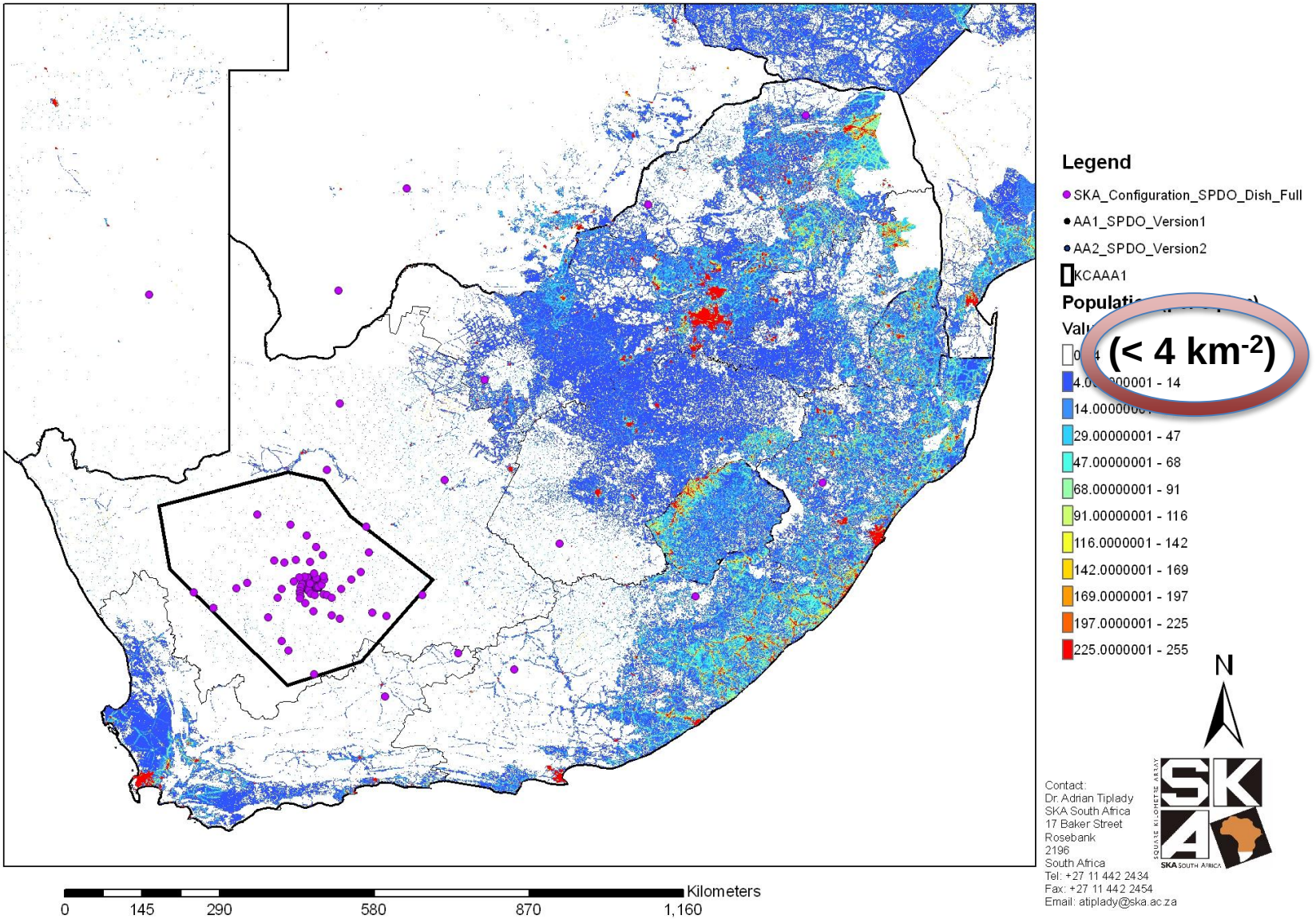


Sydney:
population 4 million

Narrabri:
population 4000

Mileura:
population 4

How did we choose the sites?



Contact:
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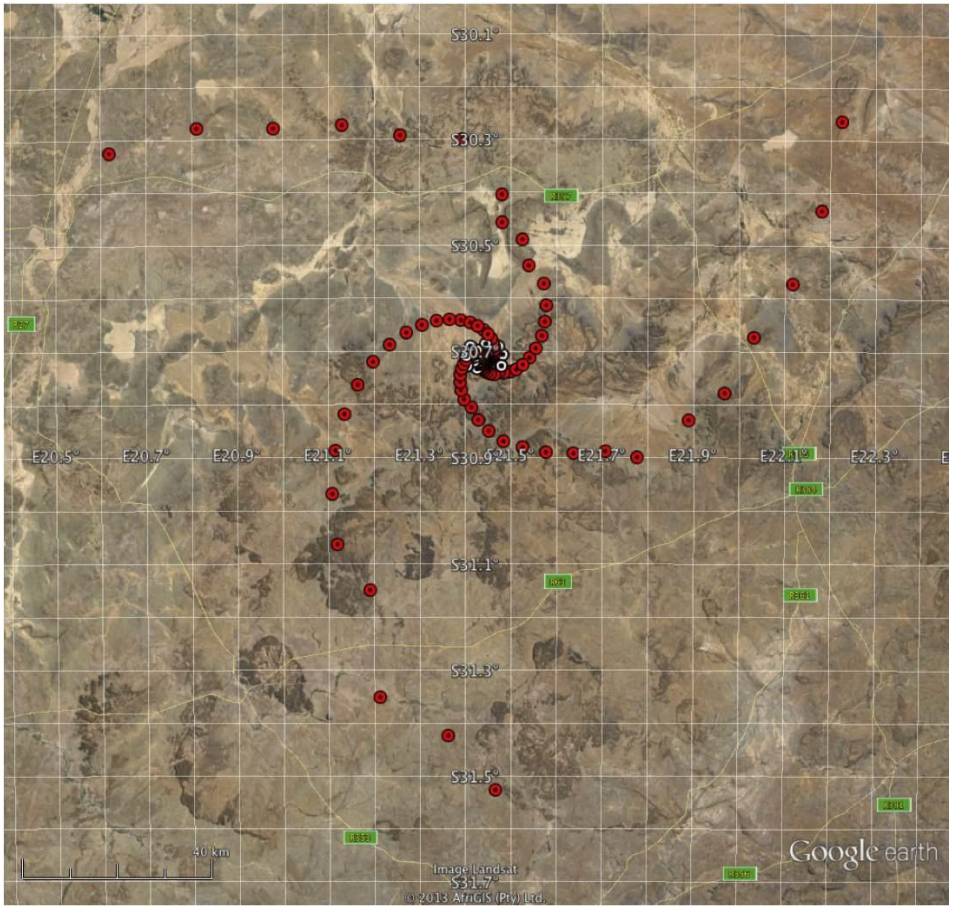
SKA South Africa
17 Baker Street
Rosebank
2196
South Africa
Tel: +27 11 442 2434
Fax: +27 11 442 2454
Email: atiplady@ska.ac.za

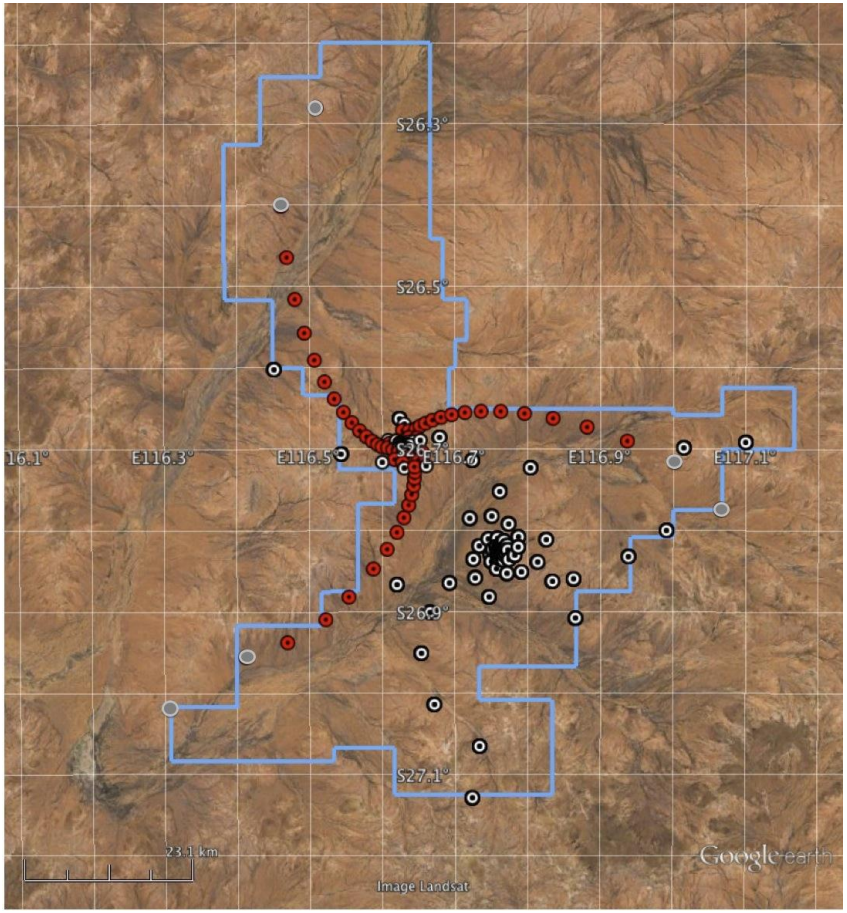
How did we choose the sites?

Shire of Murchison:

- 50,000 km²
- 0 gazetted towns
- 29 sheep/cattle stations
- 110 population (2×10^{-3} km^{-2})

SKA1 Configurations

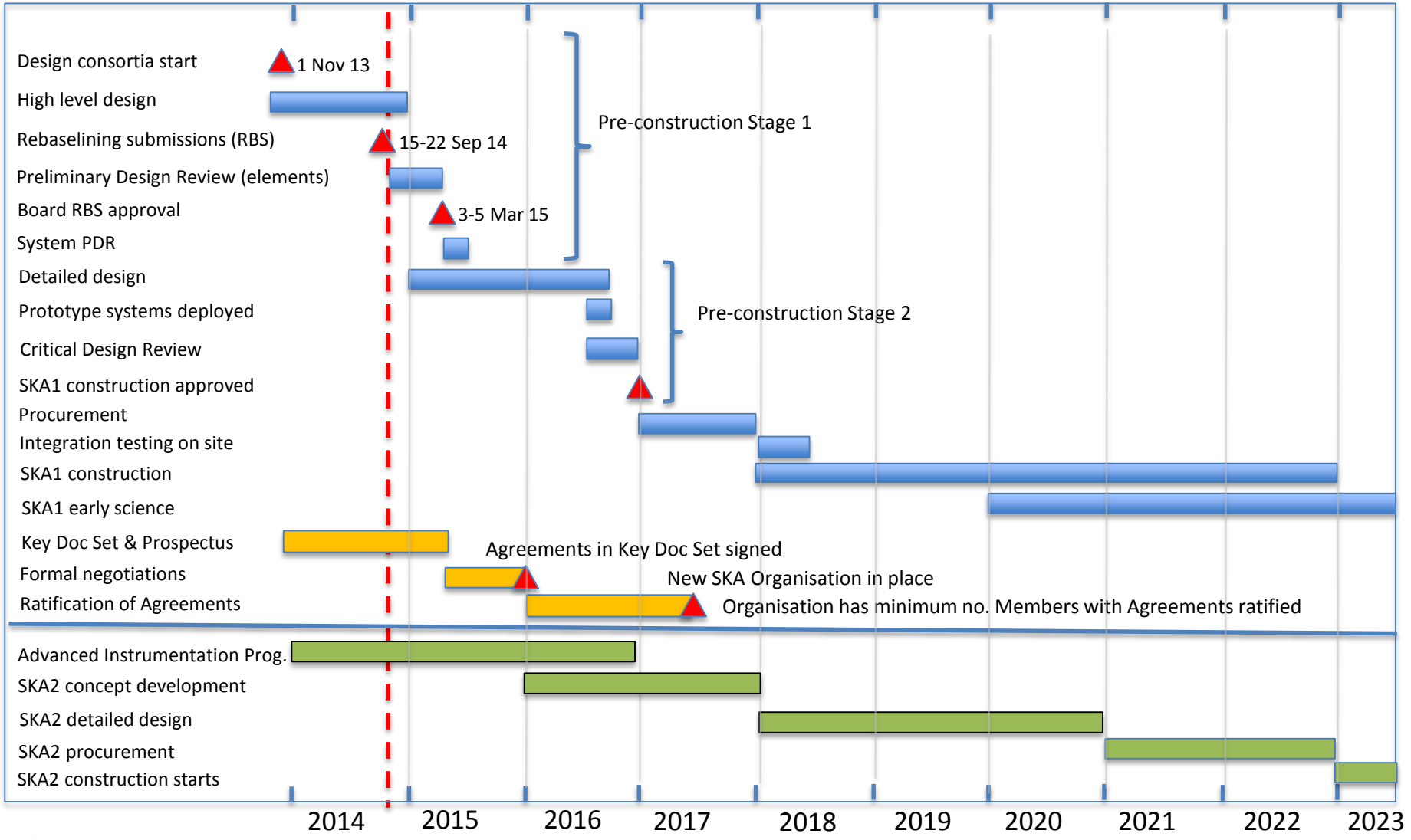




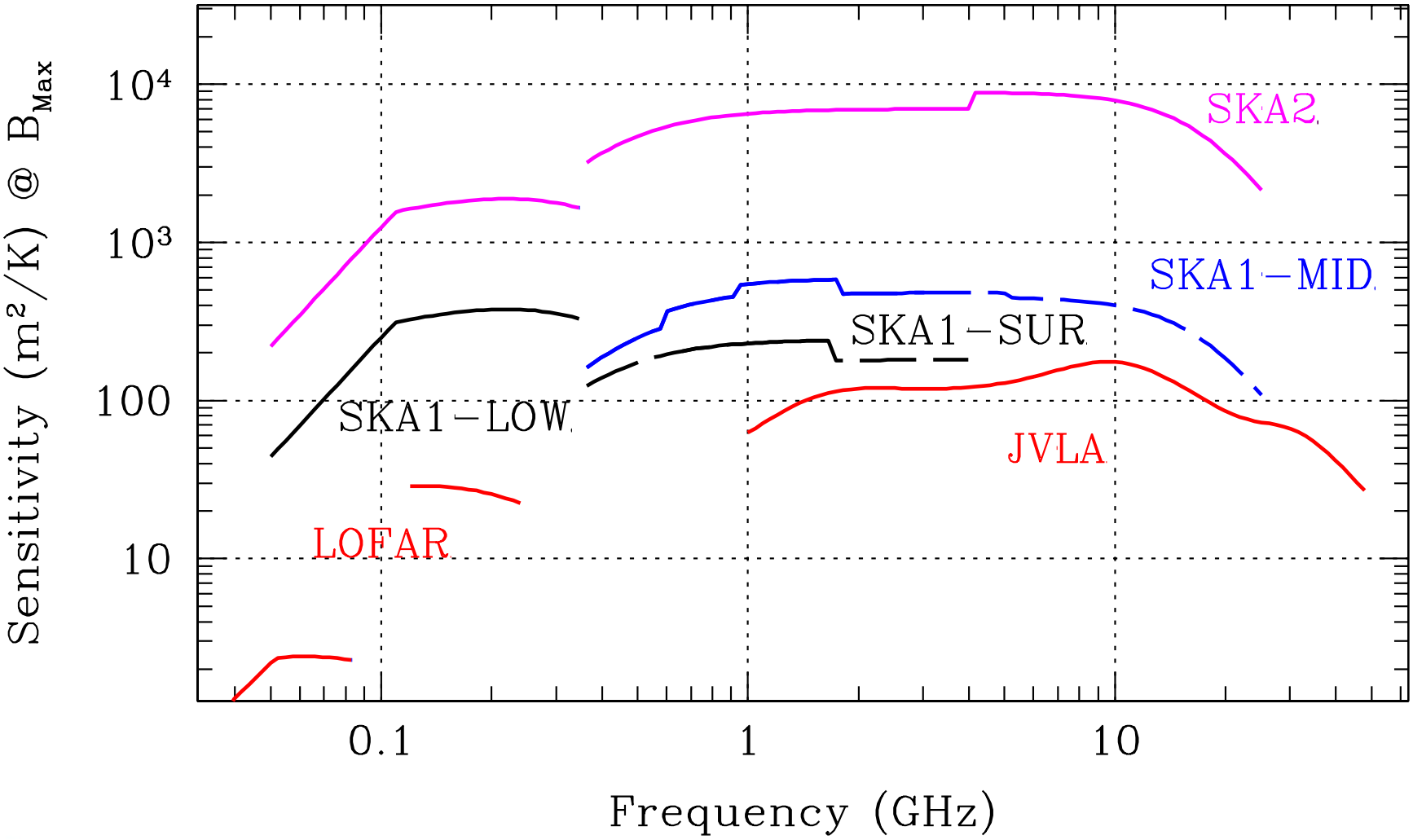
- SKA1–MID, –SUR, –LOW: B_{Max} = 156, 54, 65 km

High-level SKA1 Schedule

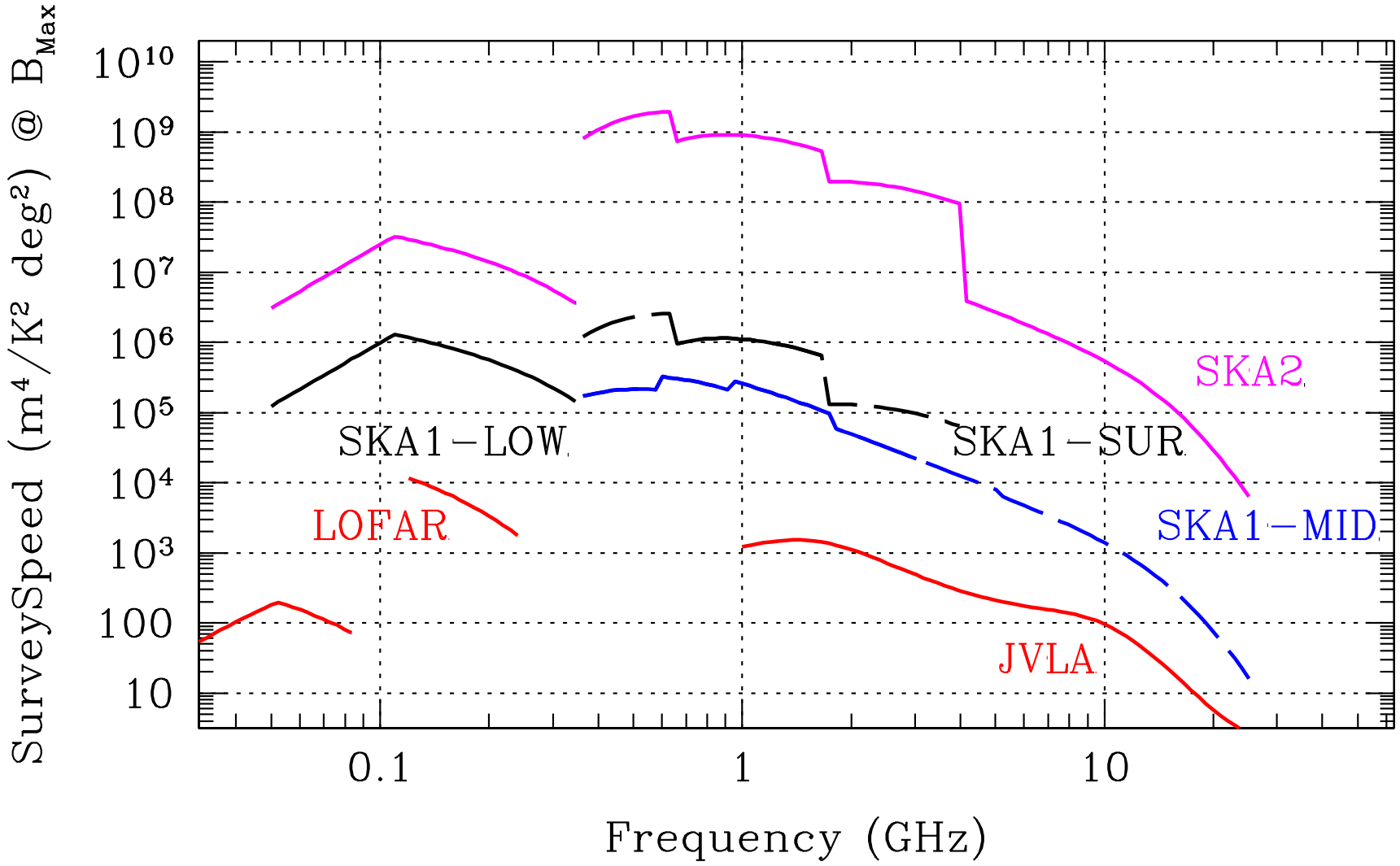
KEY: Blue = SKA1 science & engineering; orange = policy; green = SKA2



Sensitivity Comparison



Survey Speed Comparison



Resolution Comparison

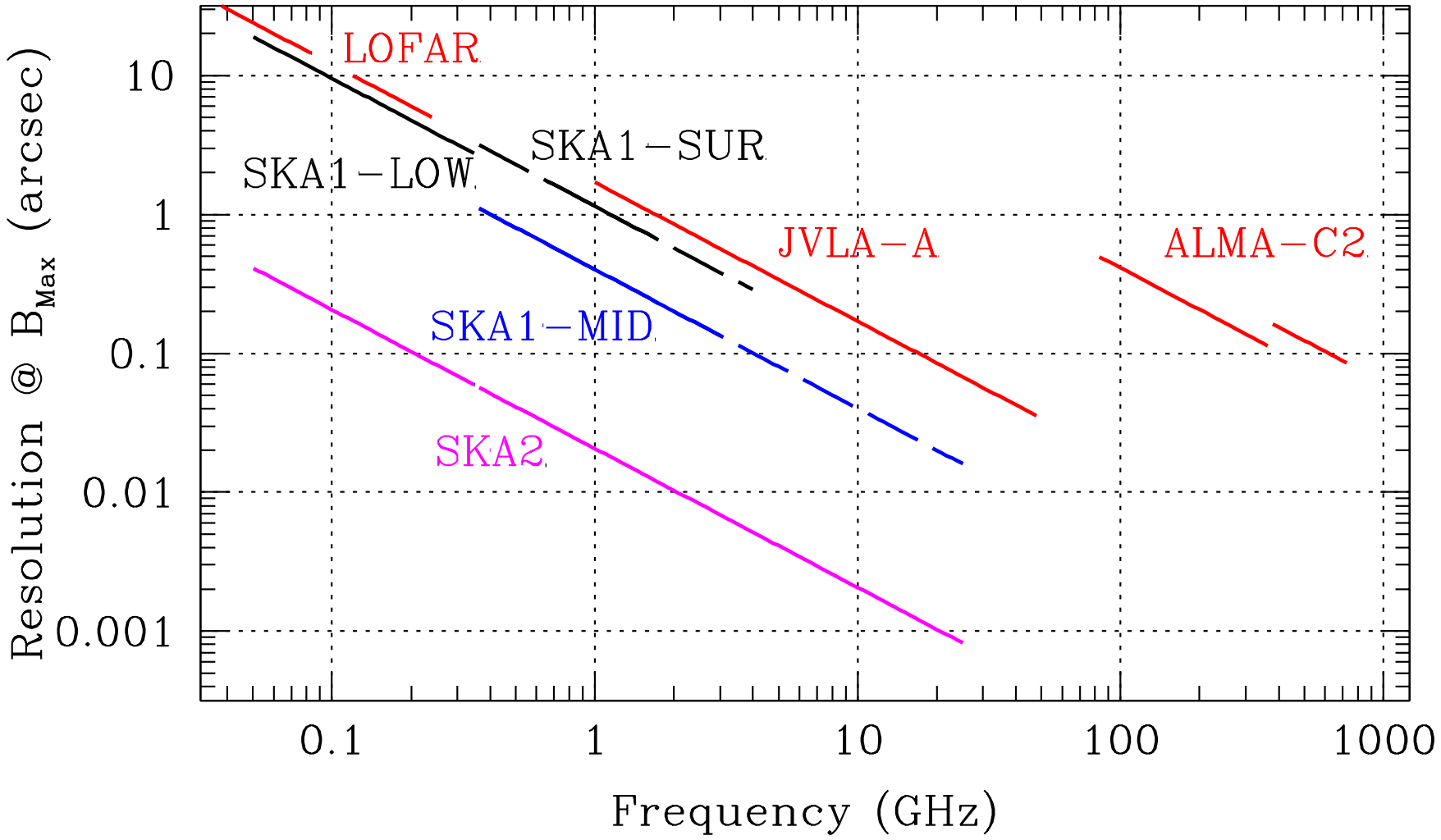
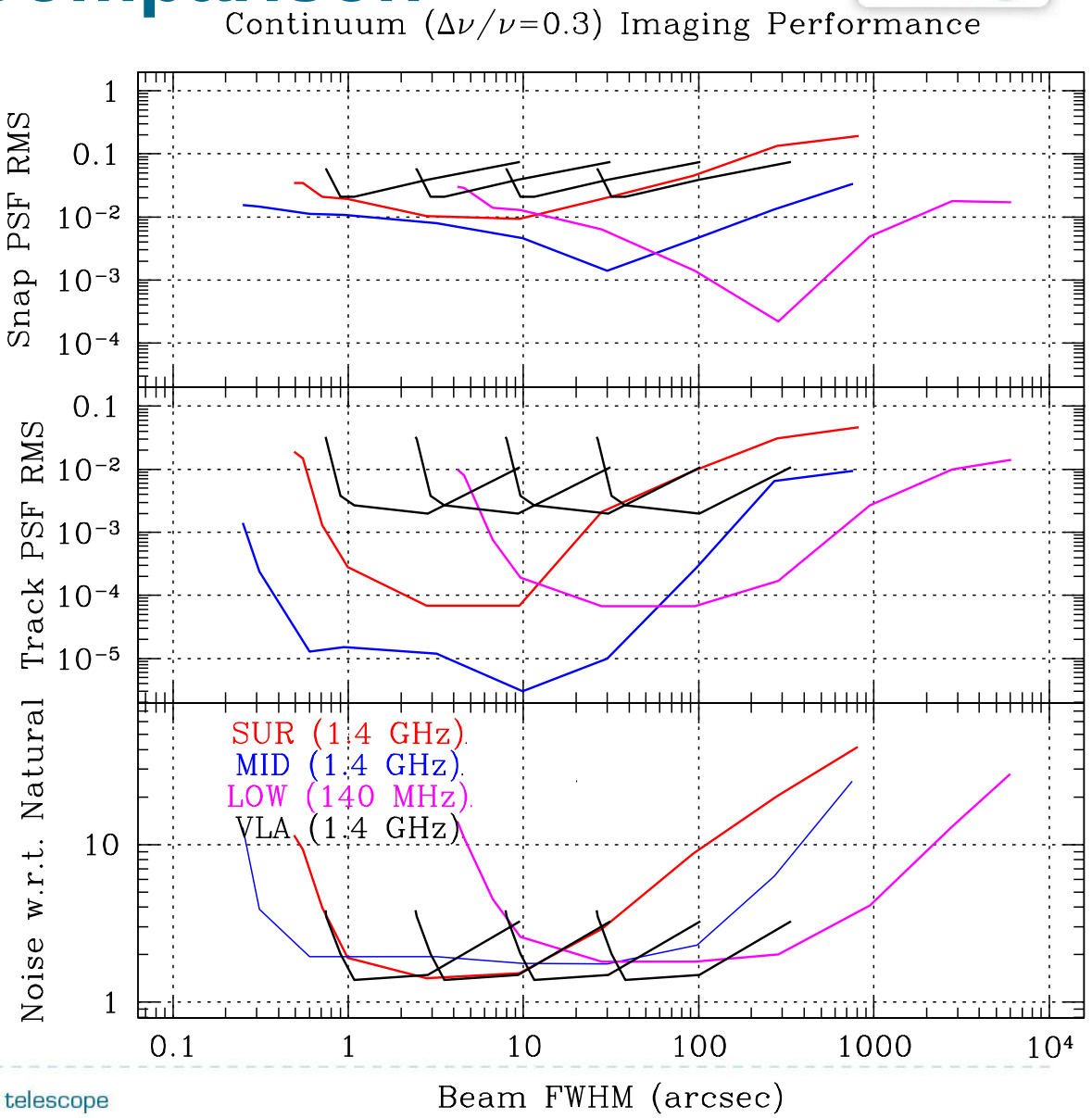


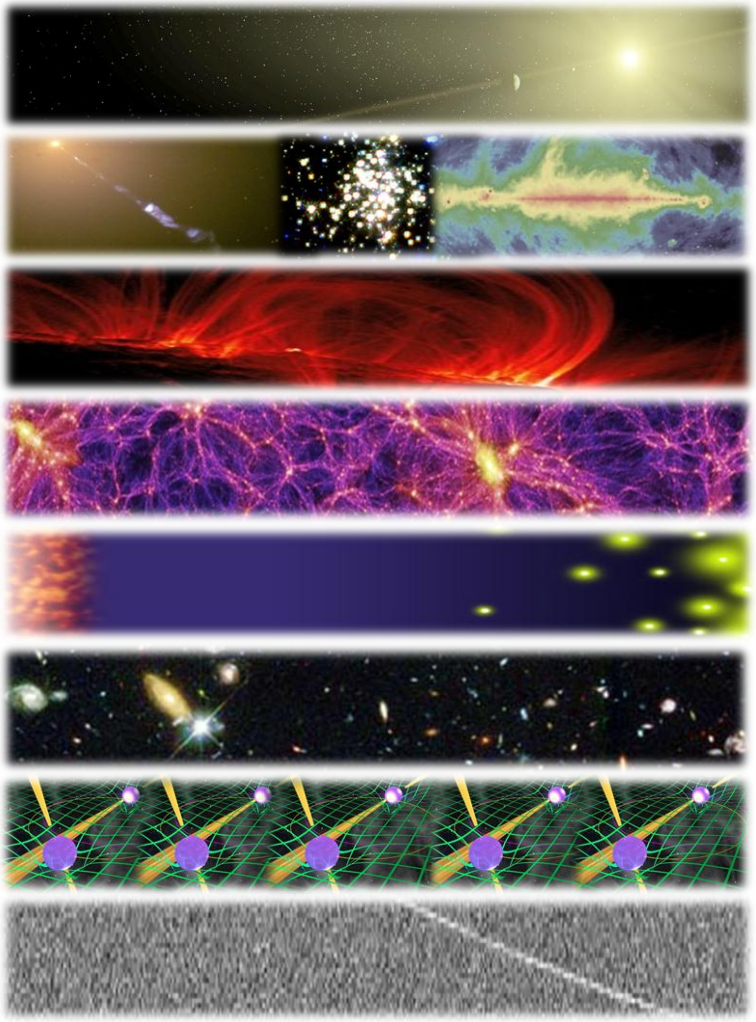
Image Quality Comparison

- Single SKA1 track equivalent to VLA A+B+C+D + **E+A$^+$**
- "Structural" dynamic range of ~1000:1 rather than ~3:1 per track



Science Working Groups

- **Astrobiology / Cradle of Life**
  - Hoare (UK)
- **Galaxy Evolution / Continuum**
  - Prandoni (IT), Seymour (AU)
- **Cosmic Magnetism**
  - Govoni (IT), Johnston-Hollitt (NZ)
- **Cosmology**
  - Maartens (ZA)
- **Epoch of Reionisation / Cosmic Dawn**
  - Koopmans (NL)
- **Galaxy Evolution / Neutral Hydrogen**
  - Staveley-Smith (AU), Oosterloo (NL)
- **Pulsars / Strong field tests of gravity**
  - Stappers (UK), Kramer (DE)
- **Transients**
  - Fender (UK), MacQuart (AU)



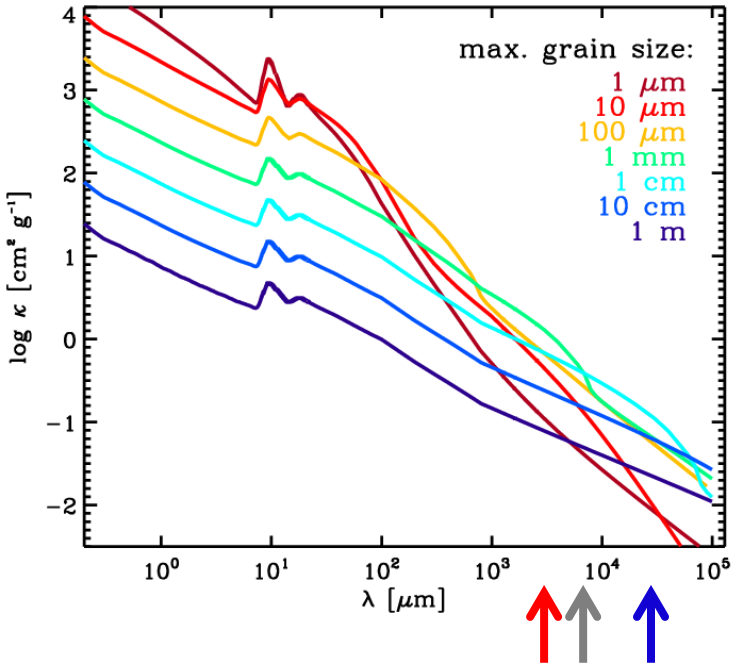
Key Science Projects: Proposal 1/3

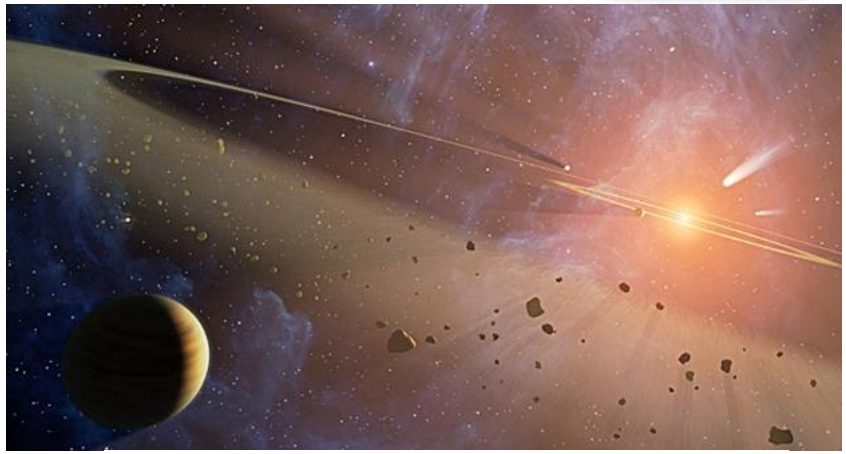
- Define **notional** package of Key Science Projects in Q1 2015 based on the highest priority science objectives that have been recommended by our science community that will be:
  - Consistent with capabilities of the re-baselined SKA1 design
  - Consistent with a realistic observing schedule filled at 50 – 70% for the first 5 years of full scientific operations, ie. 2023 – 2028 (post early science)
- Adopt KSP policy
  - Only scientists from SKA member countries may lead a KSP
  - KSP Leadership is guaranteed to be distributed amongst SKA members in proportion to their financial contribution
  - KSP participation (at the non-Leader level) is guaranteed to be distributed amongst SKA members in proportion to their financial contribution
  - KSP participation (at the non-Leader level) of SKA non-members is capped at the value defined in the Access Policy

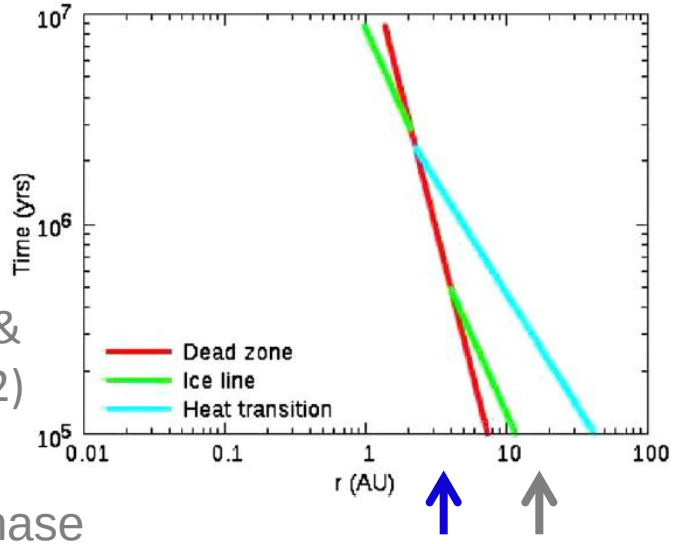
SKA1 Headline Science

- The Cradle of Life & Astrobiology
  - Proto-planetary disks
- Strong-field Tests of Gravity with Pulsars and Black Holes
  - Gravity waves and fundamental physics
- The Origin and Evolution of Cosmic Magnetism
  - The role of magnetism in galaxy evolution
- Galaxy Evolution probed by Neutral Hydrogen
  - Resolved gaseous disks and angular momentum growth
- The Transient Radio Sky
  - Fast Radio Bursts as cosmological probes
- Galaxy Evolution probed in the Radio Continuum
  - Star formation rates and resolved disks
- Cosmology & Dark Energy
  - Primordial non-Gaussianity, super-horizon scales and the matter dipole
- Cosmic Dawn and the Epoch of Reionization
  - Direct imaging of the earliest structures

The Cradle of Life: Understanding planet formation





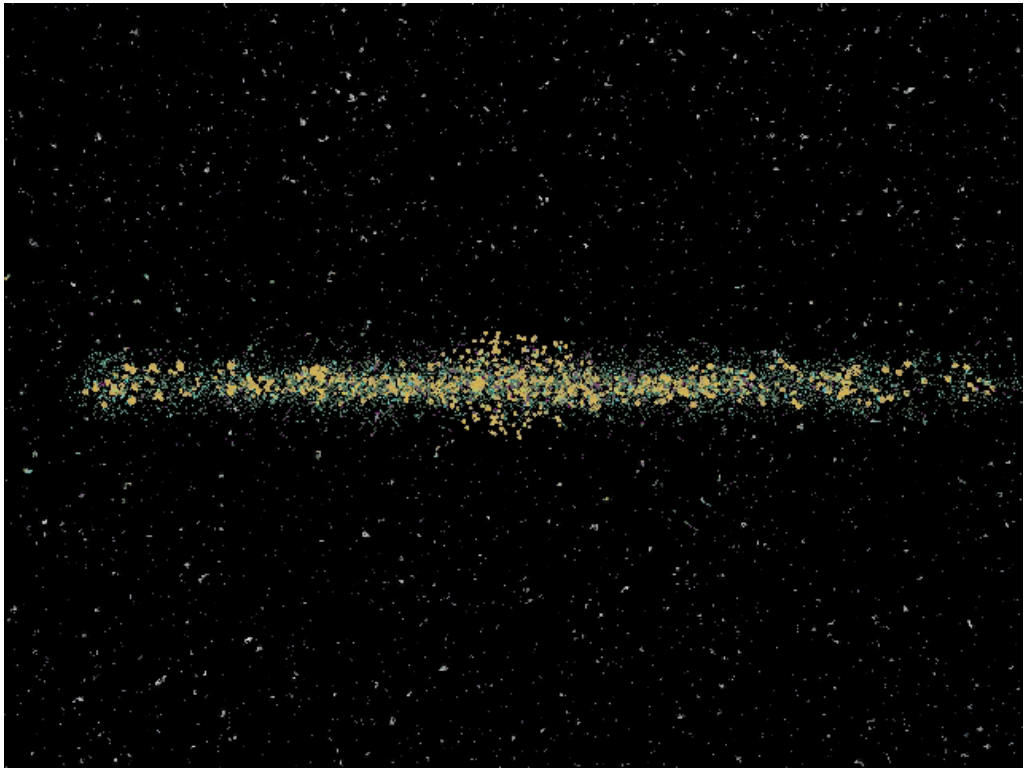


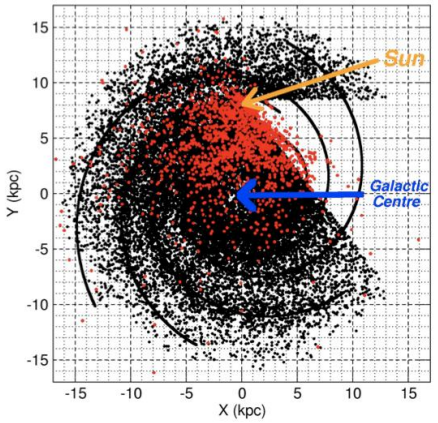
(Hasegawa & Pudritz 2012)

- Measuring grain growth through planetesimal phase
- Resolving proto-planetary disks at 100 pc inside the snow/ice line

Finding all the pulsars in the Milky Way…

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

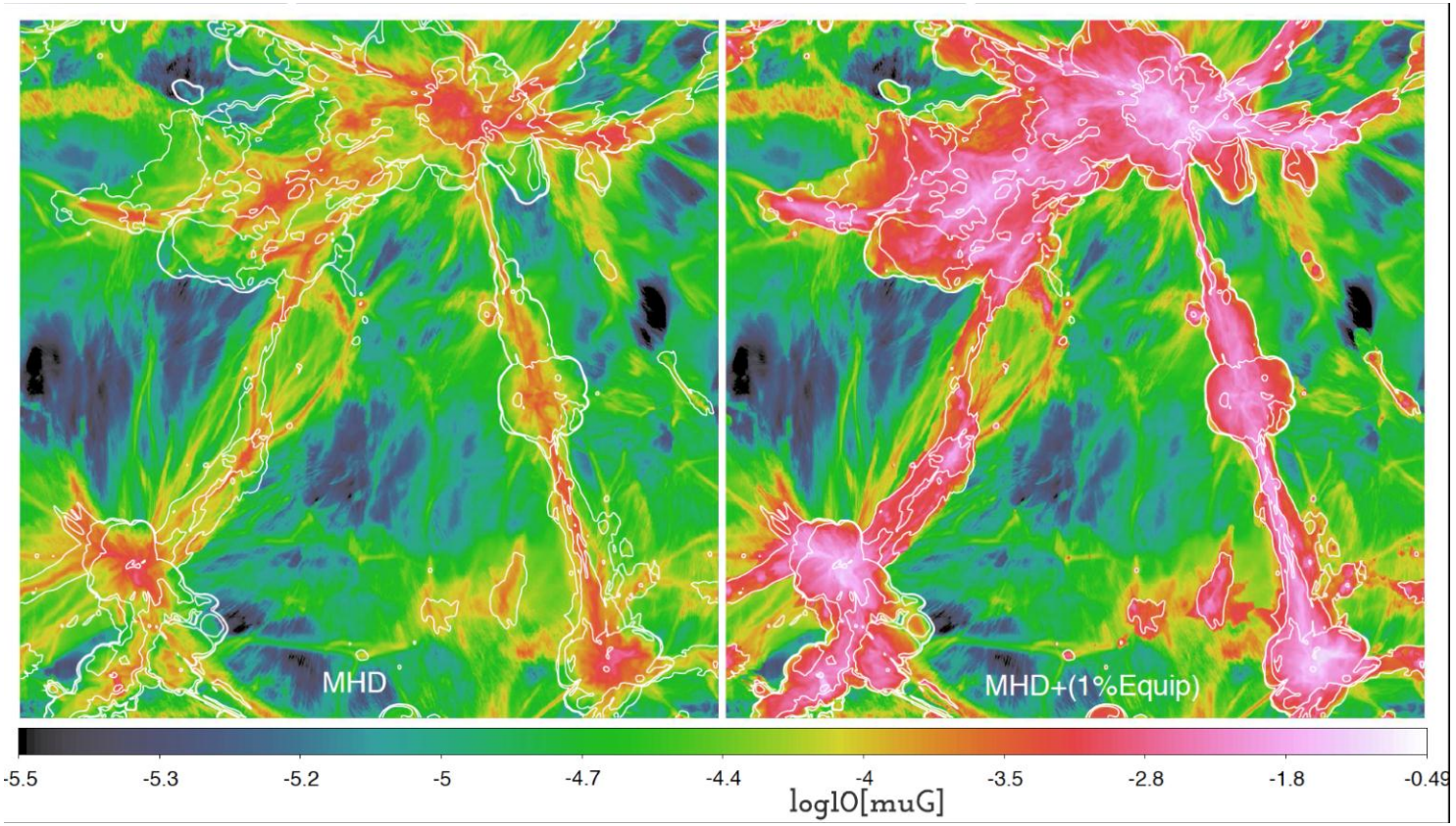




- ~30,000 normal pulsars
- ~2,000 millisecond psrs
- ~100 relativistic binaries
- first pulsars in Galactic Centre
- first extragalactic pulsars

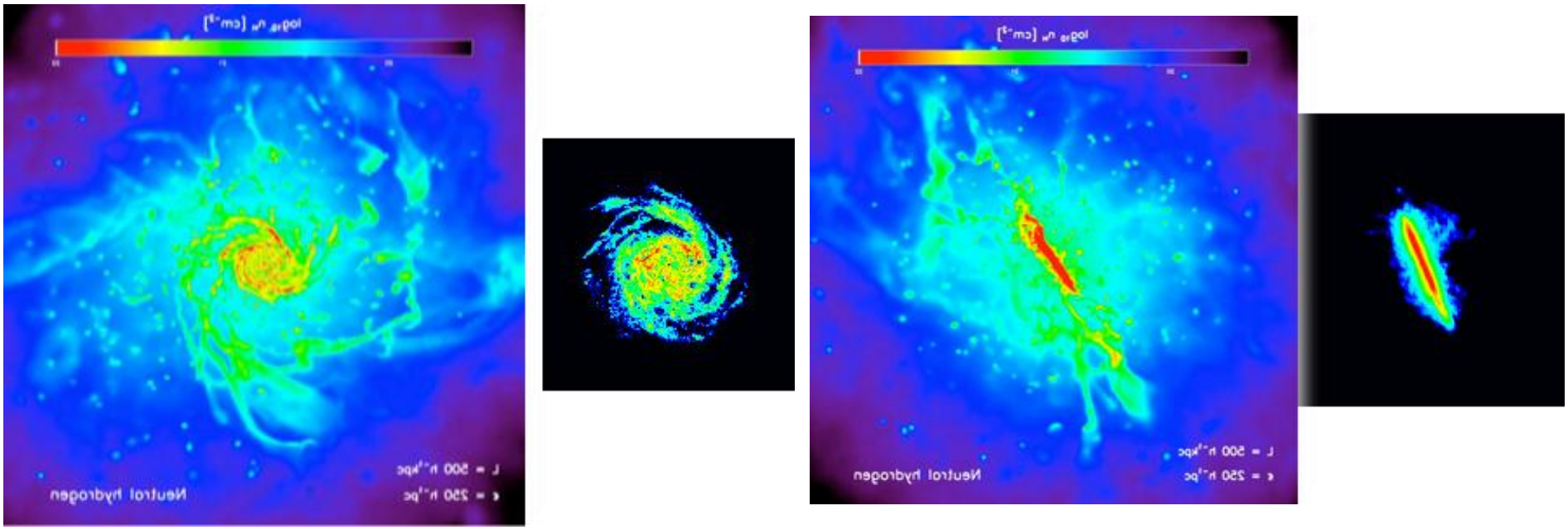
- Timing precision is expected to increase by factor ~100
- Rare and exotic pulsars and binary systems: including PSR-BH systems!
- Testing cosmic censorship and no-hair theorem
- **Current estimates are that ~50% of entire Galactic population in reach of SKA1**

The Magnetic Universe:
Understanding the origin and evolution of B fields



- Determine the role of magnetism in regulating galaxy evolution
- Detection and characterization of the magnetic cosmic web
- Magnetic evolution of AGN over cosmic time

Galaxy Evolution with SKA1: Resolved HI Kinematics out to z ~ 0 – 0.8

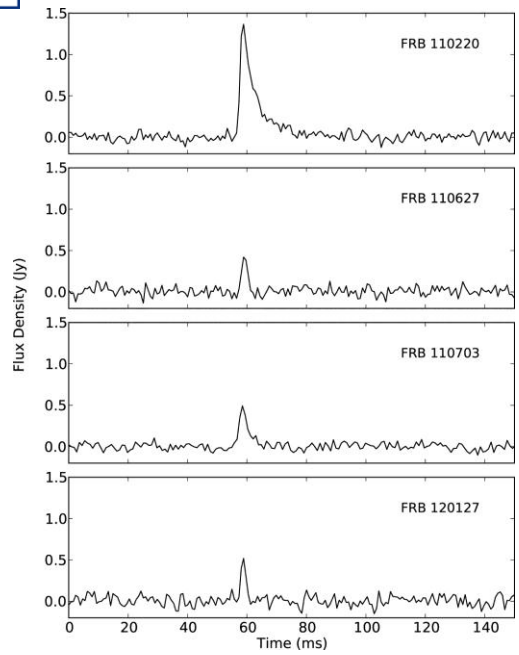


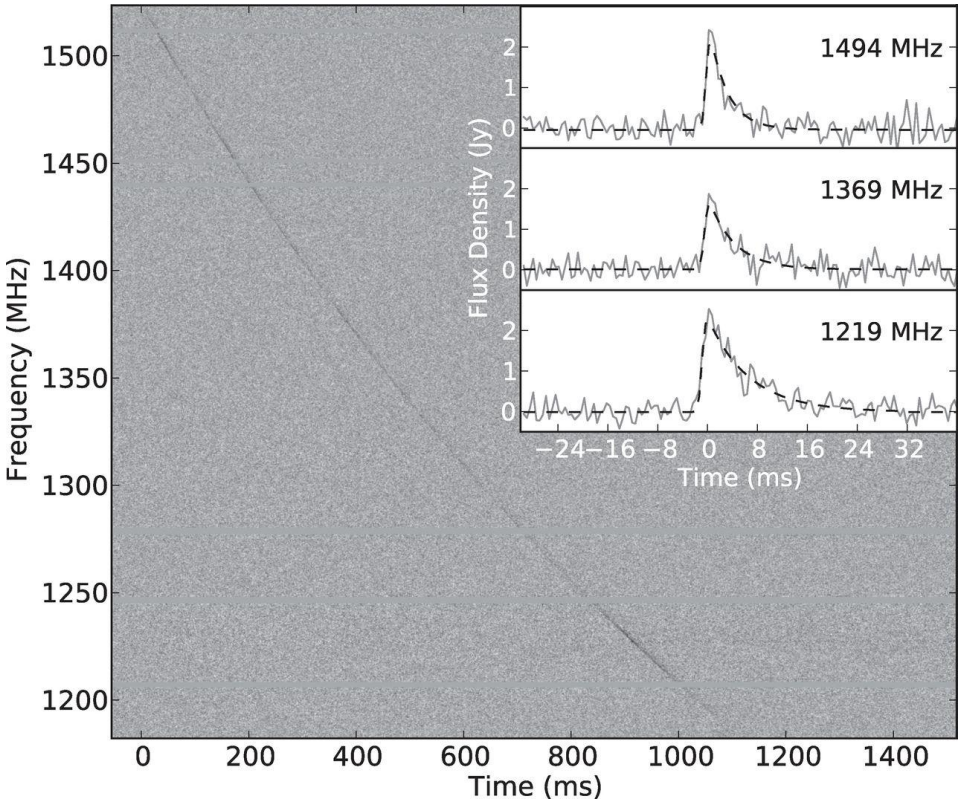
(Simulations: Schaye et al. 2010, Images: Oosterloo 2014)

- Understanding galaxy assembly and the baryon cycle
  - Determine the impact of galaxy environments
  - Probe gas inflow and removal
  - Measure angular momentum build-up

The Transient radio sky

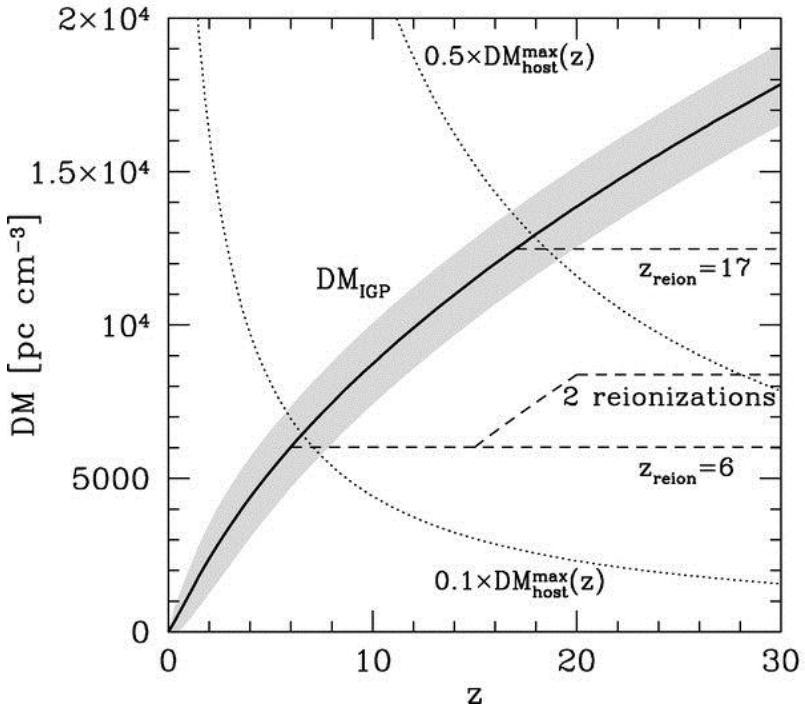
A Population of Fast Radio Bursts at Cosmological Distances
D. Thornton *et al.*
Science **341**, 53 (2013);
DOI: 10.1126/science.1236789



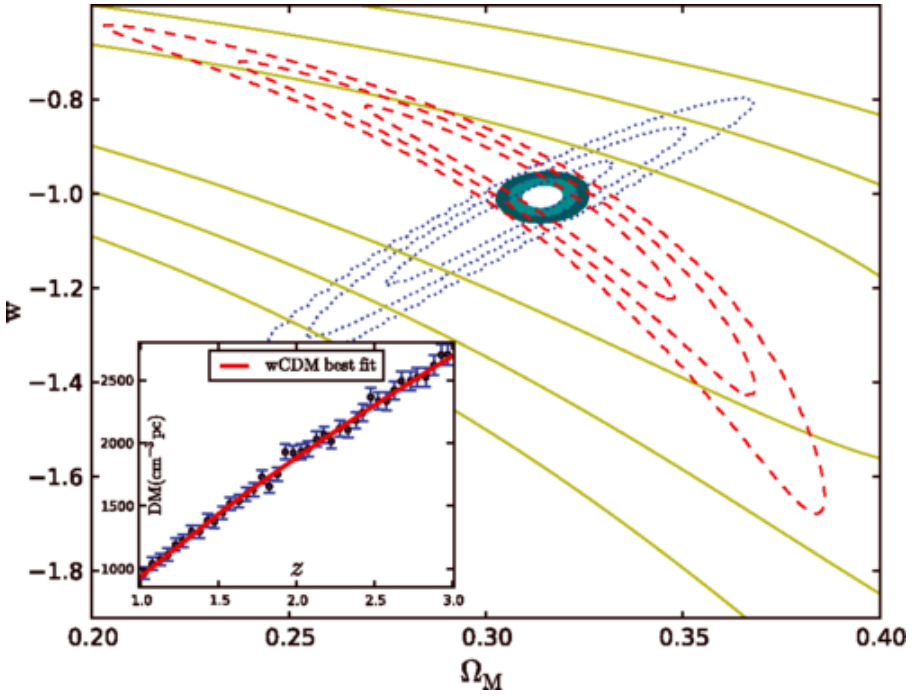


- Four celestial “FRB” events now detected (after first “Lorimer” burst):
  S = 0.5 – 1.3 Jy, Δt = 1 – 6 msec, DM = 550 – 1100 cm^{-3} pc
- Estimated event rate: $1x10^4$ sky^{-1} day^{-1}
- Completely unknown origin, possibly at cosmological distances

The Transient radio sky: Fast Radio Bursts as a cosmological probe



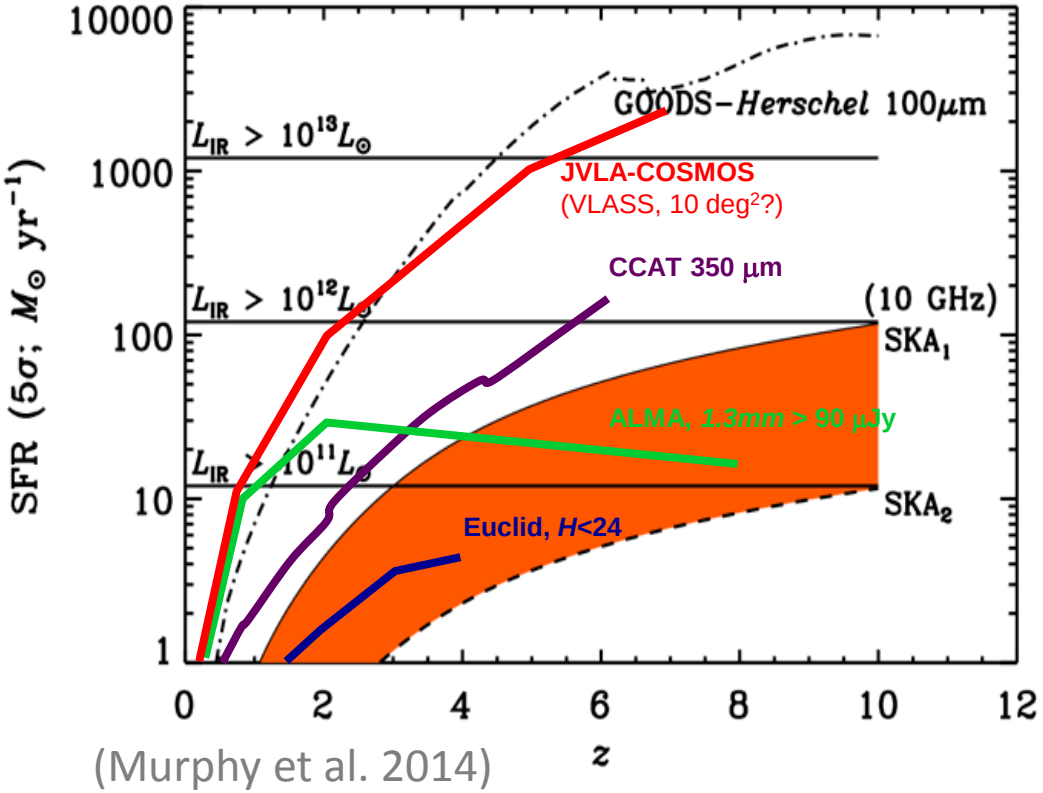
(Ioka 2003)



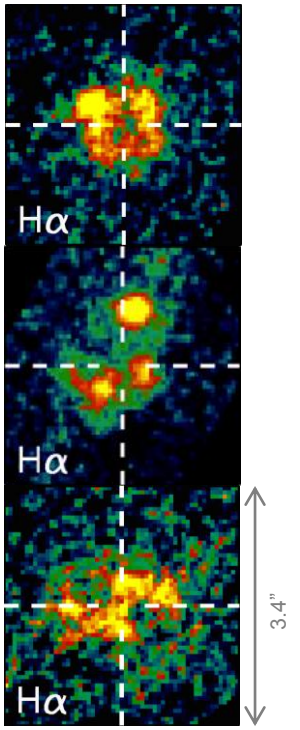
(Zhou et al. 2014)

- Prospects for fundamental contributions to cosmology with large samples (~1000) of spectroscopically identified FRBs

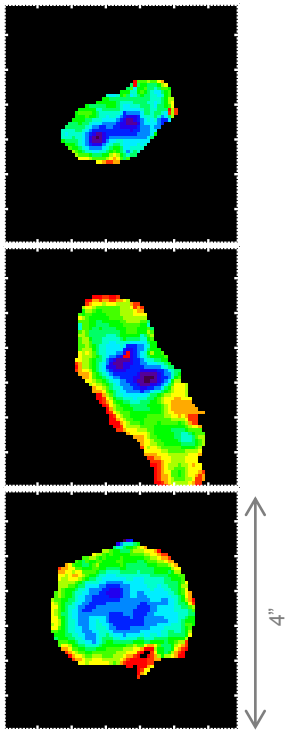
Galaxy Evolution Studies in the Radio Continuum: Understanding the Star Formation History of the Universe



(Murphy et al. 2014)



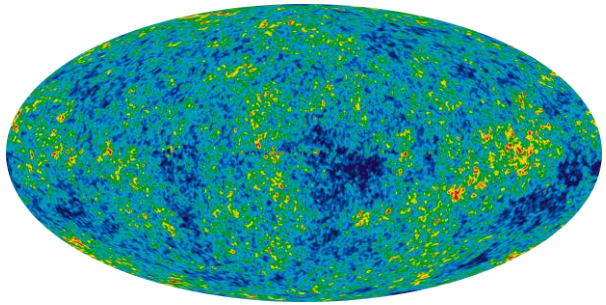
Wuyts et al 2013, **z~1**
Hα–based SFR-maps

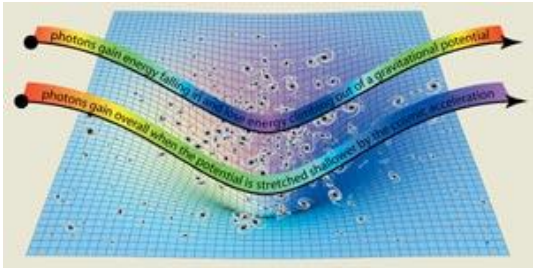


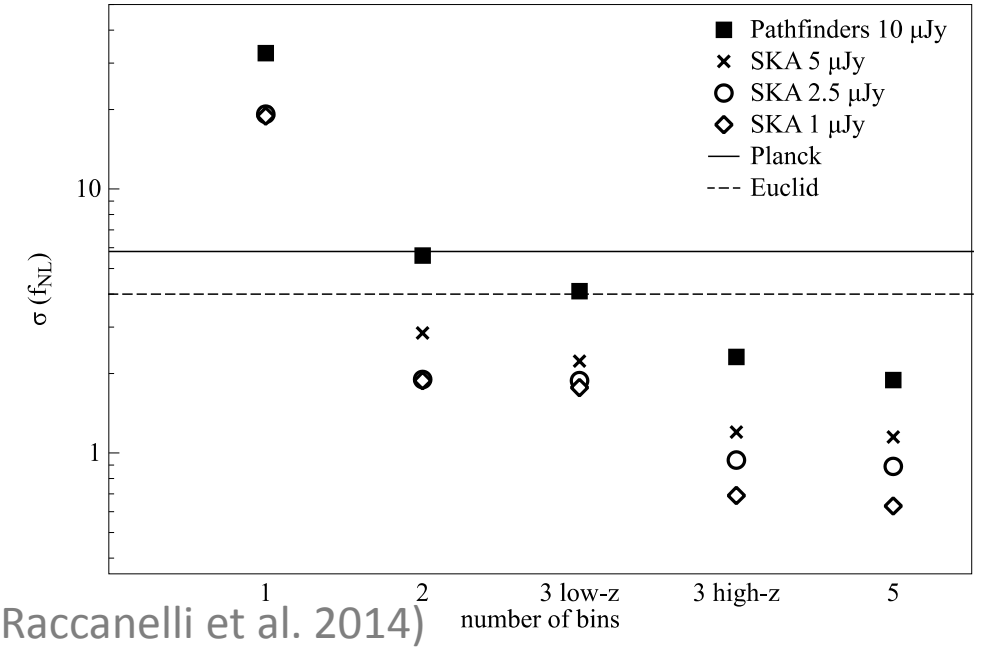
Cibinel et al 2014, **z~2**
UV-based SFR-maps

- Unmatched sensitivity to star formation rates out to z ~ 4
- Resolved imaging of star forming disks out to z ~ 2

Cosmology with SKA1: Integrated Sachs-Wolfe effect



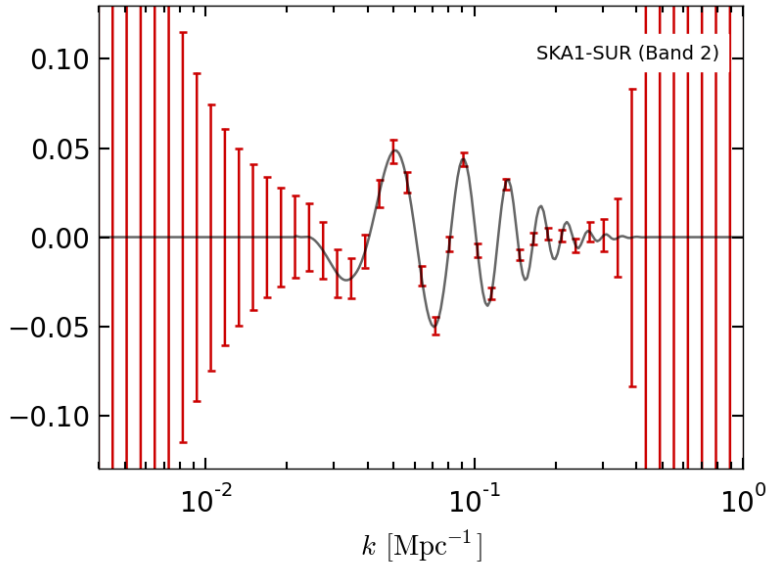




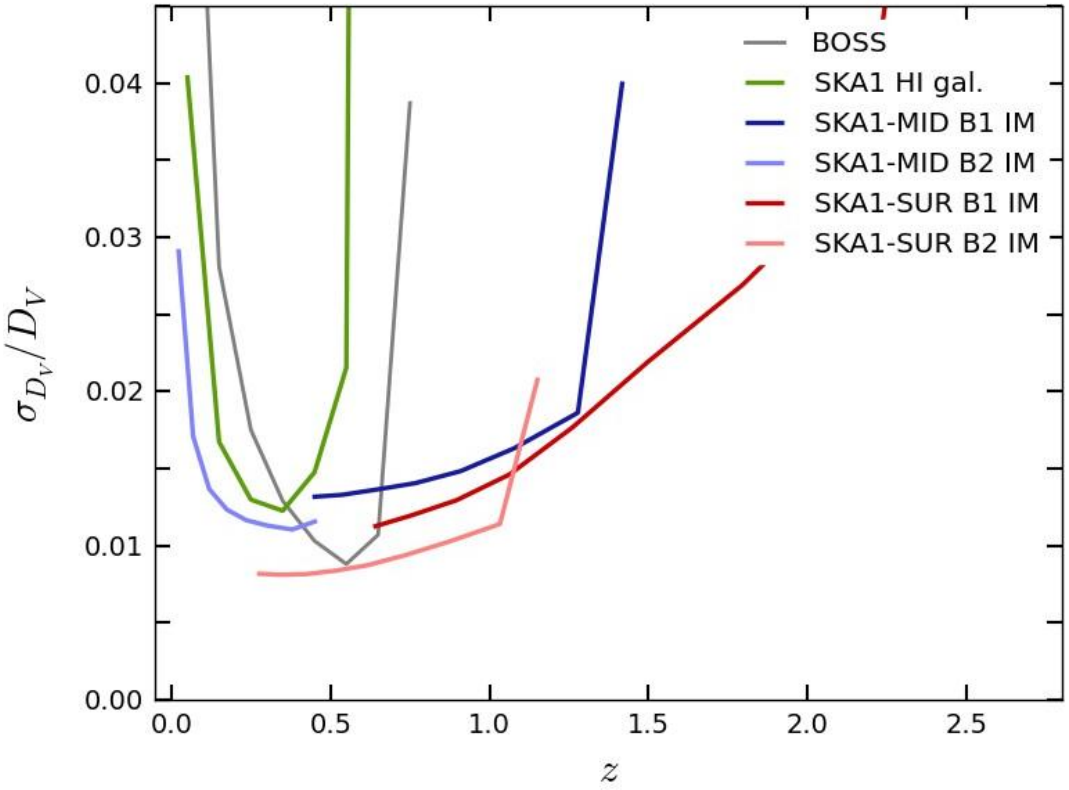
(Raccanelli et al. 2014)

- Constraining non-Gaussianity of primordial fluctuations with the Integrated Sachs-Wolfe effect: correlation of foreground source populations with CMB structures
  - Uniquely probing the largest scales

Cosmology with SKA1: Baryon Acoustic Oscillations

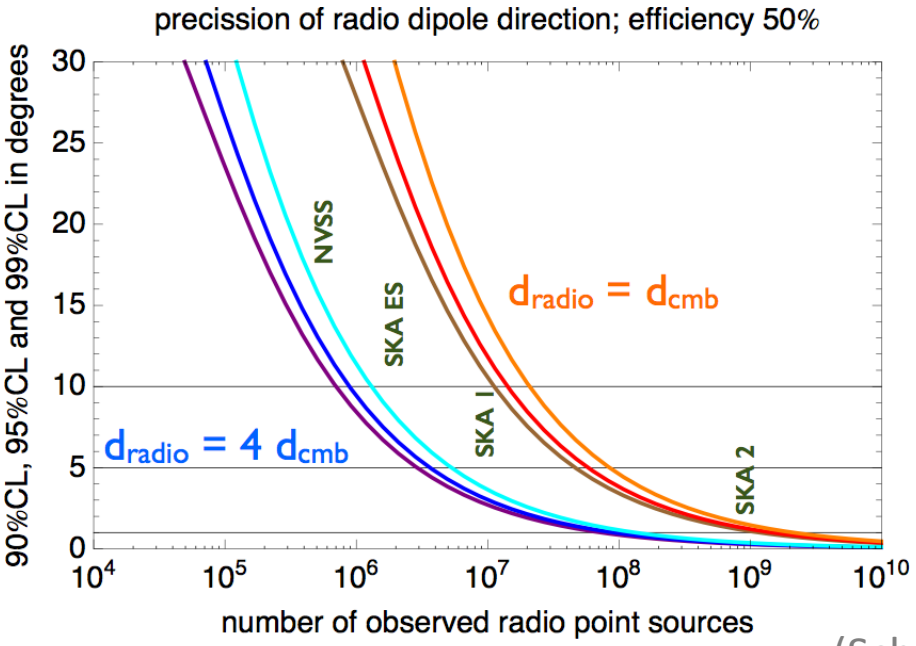


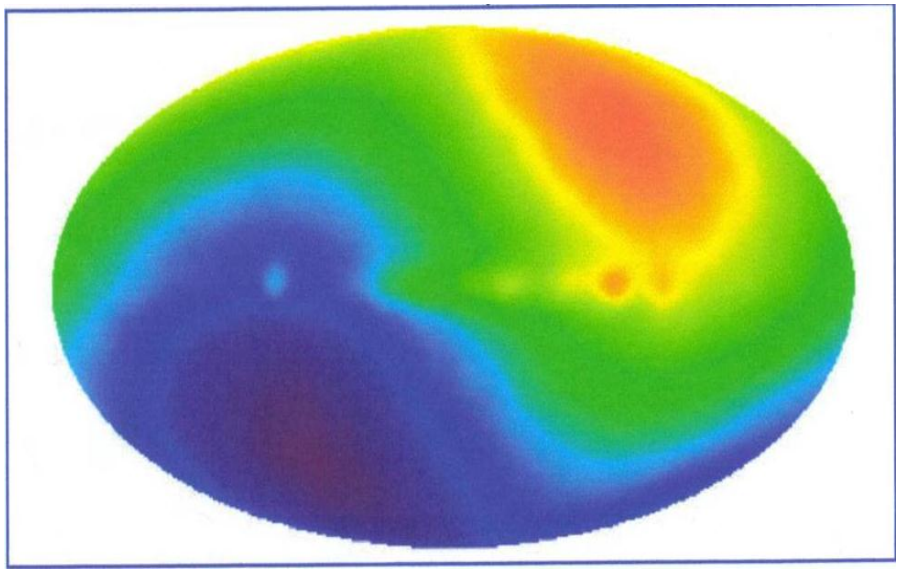
(Bull et al 2014)



- Constraining Dark Energy models with redshift-resolved BAO measurements
  - Discrete detection is complementary but not cutting edge
  - Intensity mapping is higher risk but world-class

Cosmology with SKA1: Matter Dipole versus CMB Dipole





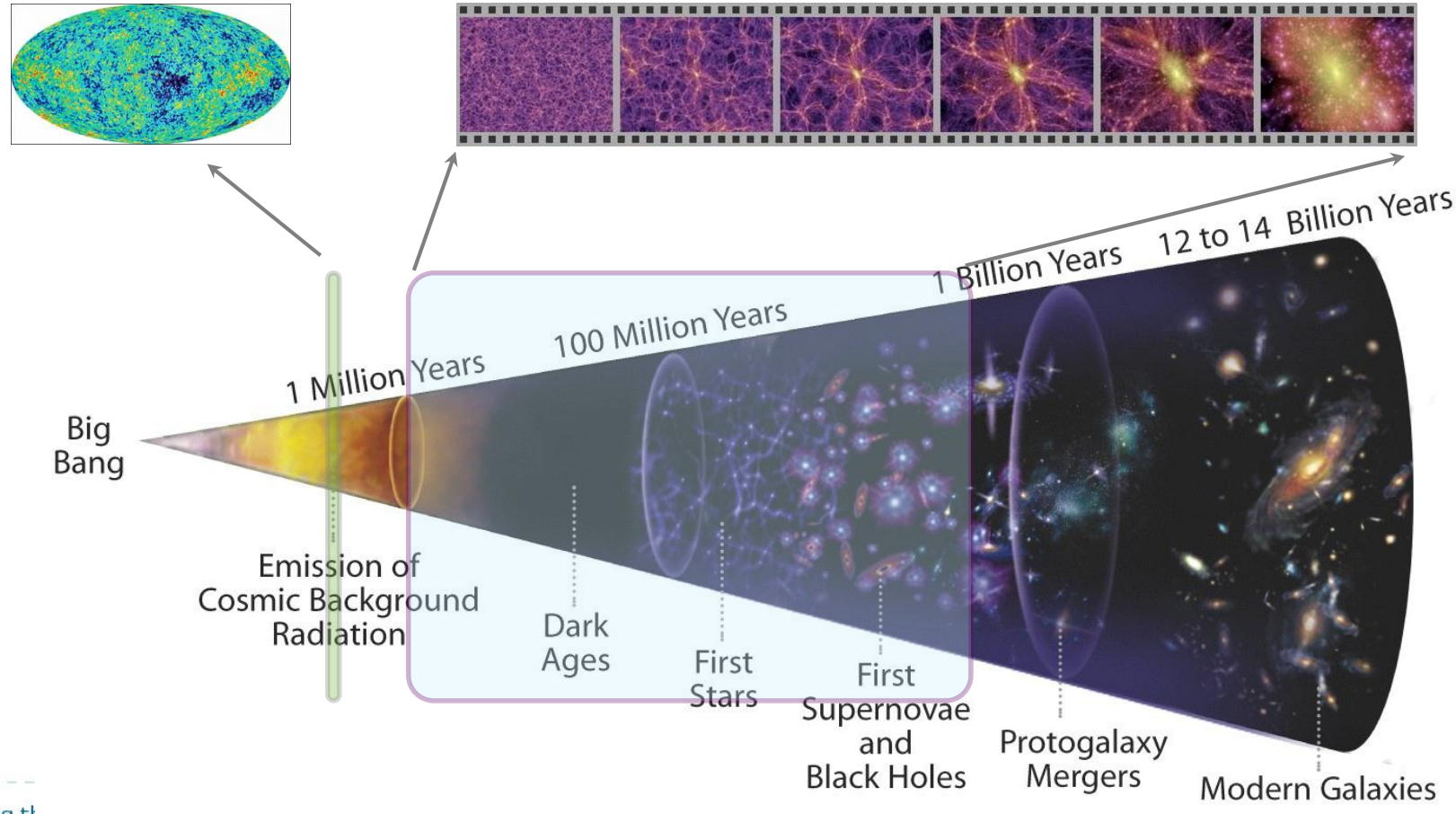
(Schwarz et al. 2014)

- Sensitive constraints on isotropy and homogeneity
  - Unique tests of isotropy at z ~ 1
  - Measure cosmic matter dipole with high precision

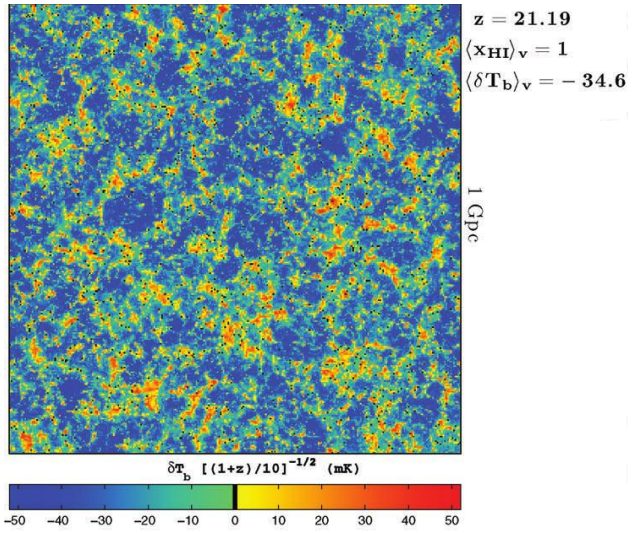
HI surveys of the EoR & Cosmic-Dawn

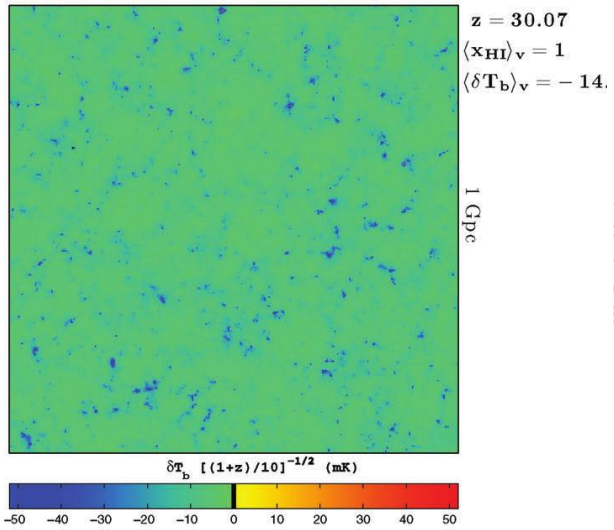
CMB displays a single moment of the Universe. Its initial conditions at ~400,000 yrs

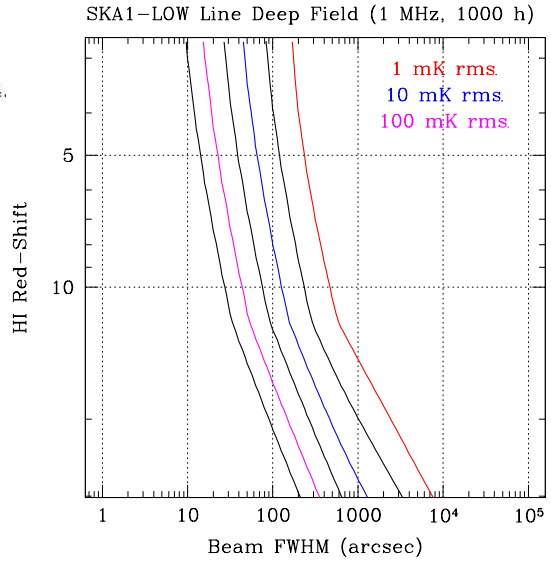
HI emission from the Dark Ages, Cosmic Dawn & EoR traces an evolving "movie" of baryonic and DM structure formation at $t_{univ}<10^9$ years.



HI surveys of the EoR & Cosmic-Dawn







(Mesinger et al 2011)

- **Detecting EoR structures in imaging mode (as distinct from statistically) on 5 arcmin scales with 1 mK RMS**
- **Probing the Cosmic Dawn statistically or possibly even imaging in ultra-deep**

Advancing Astrophysics

with the Square Kilometre Array

9-13 June 2014, Giardini Naxos, Italy

#skascicon14

2014 marks 10 years since the publication of the comprehensive **'Science with the Square Kilometre Array'** book and 15 years since the first such volume appeared in 1999. In that time numerous and unexpected advances have been made in the fields of astronomy and physics relevant to the capabilities of the Square Kilometre Array (SKA). This meeting will facilitate the publication of a new, updated science book, which will be relevant to the current astrophysical context.

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SKA Science Book:

- Meeting Program based on advanced Chapter drafts
- Contributions matched to instrumental capabilities:
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- 140 self-contained chapters, most now on arXiv
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SKA Science Book:

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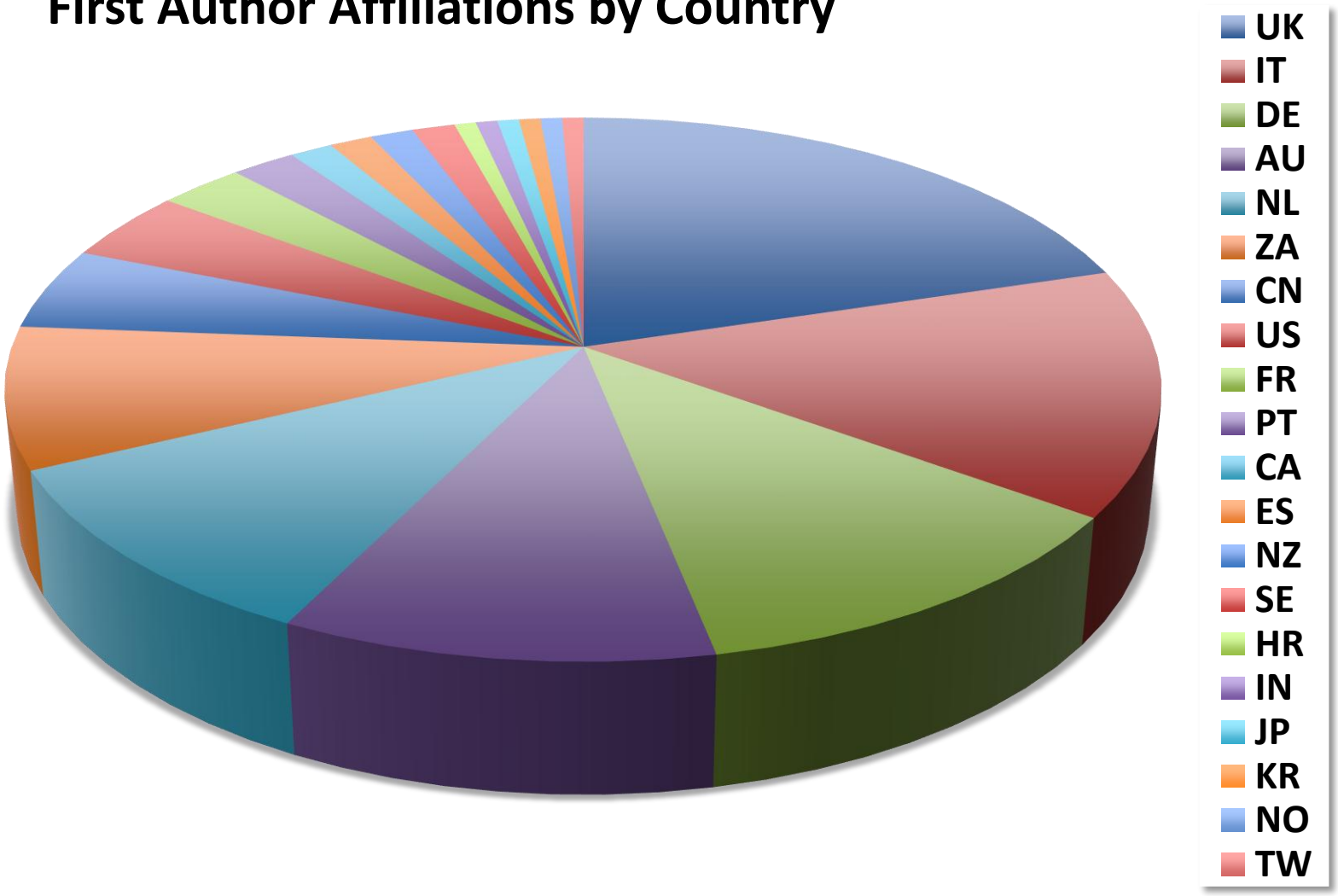

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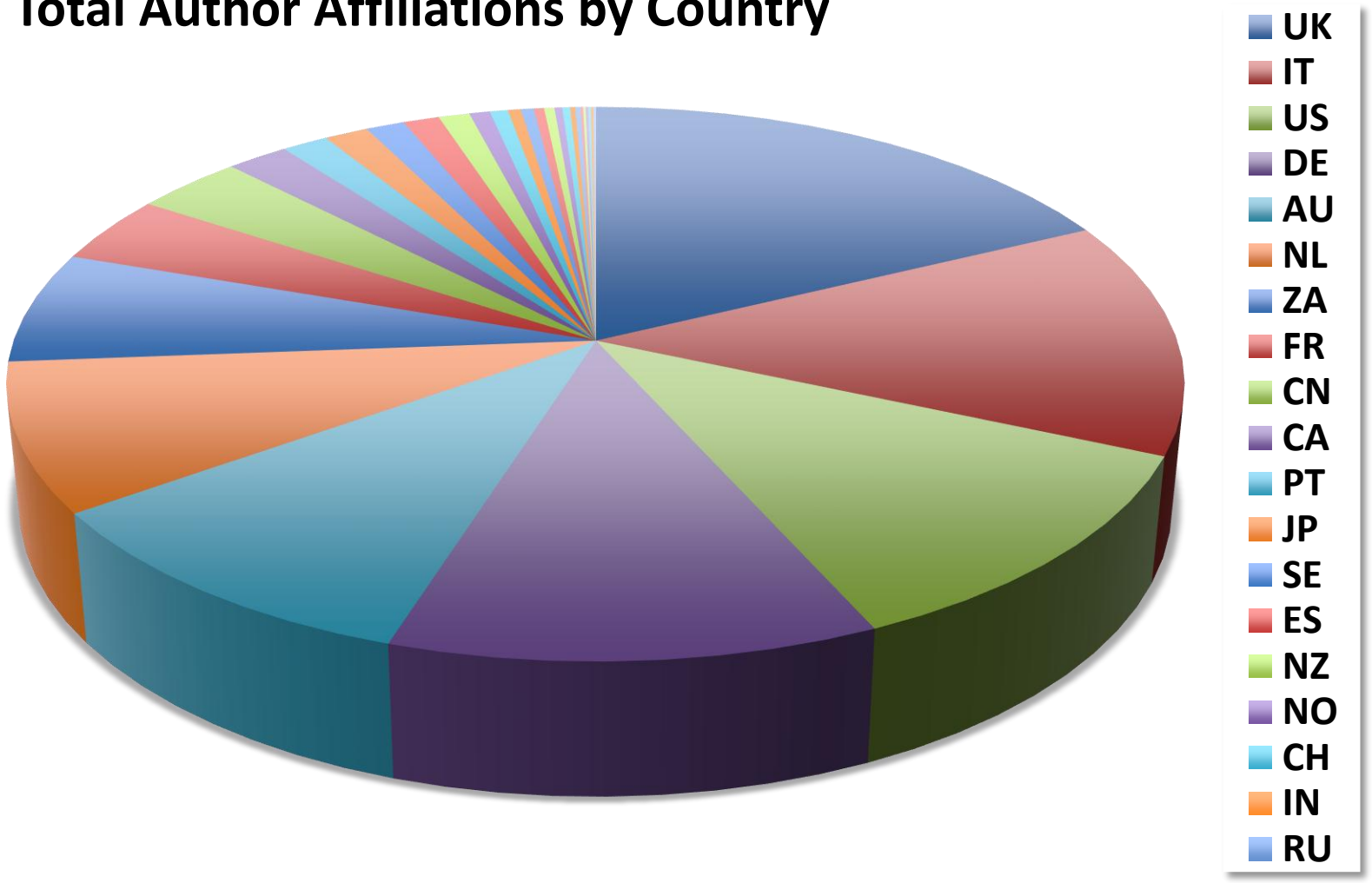

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