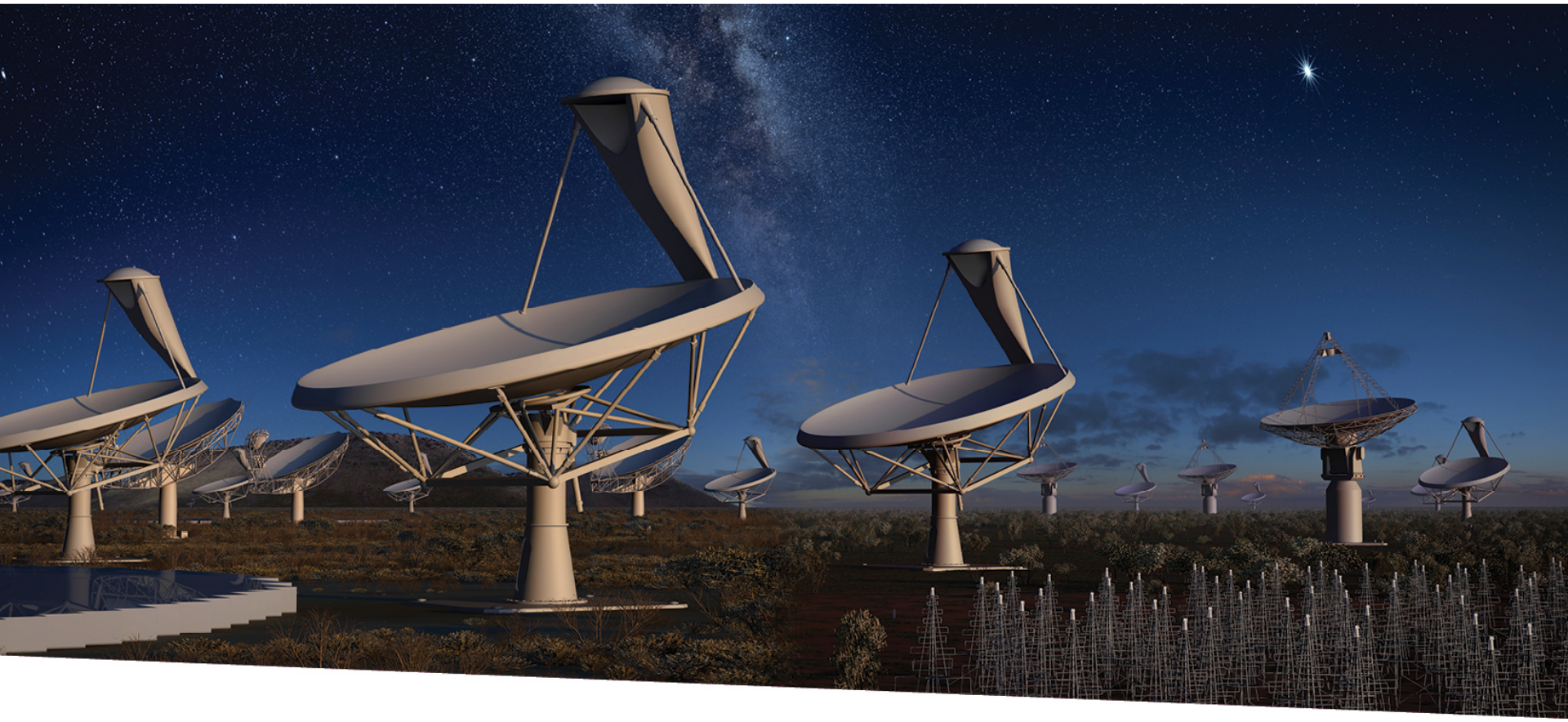
Science Capabilities of the SKA



SQUARE KILOMETRE ARRAY

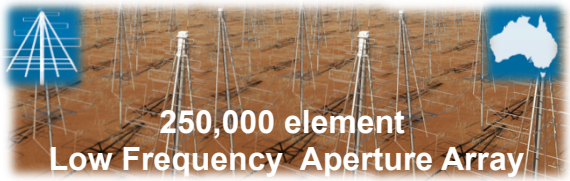
Exploring the Universe with the world's largest radio telescope

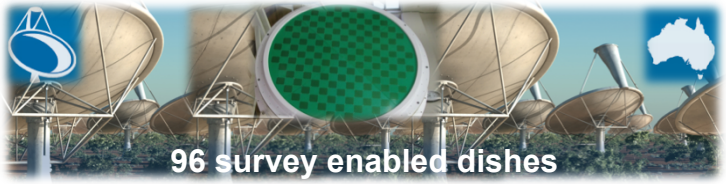
Robert Braun

9 June 2014

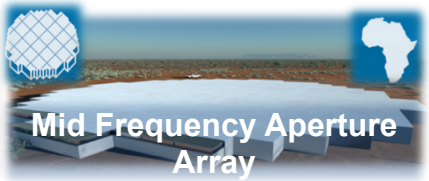
What is the SKA?

Phase I : 2020

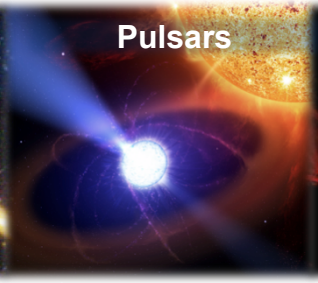


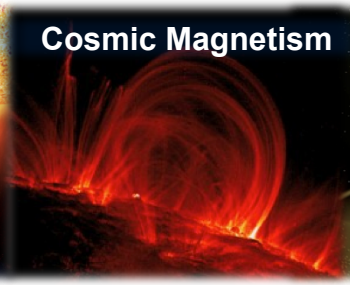


Phase II : 2024



Science

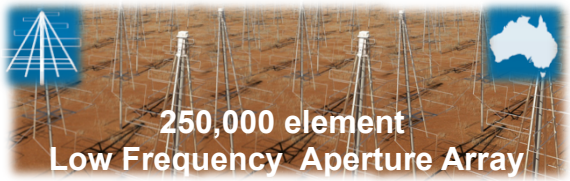


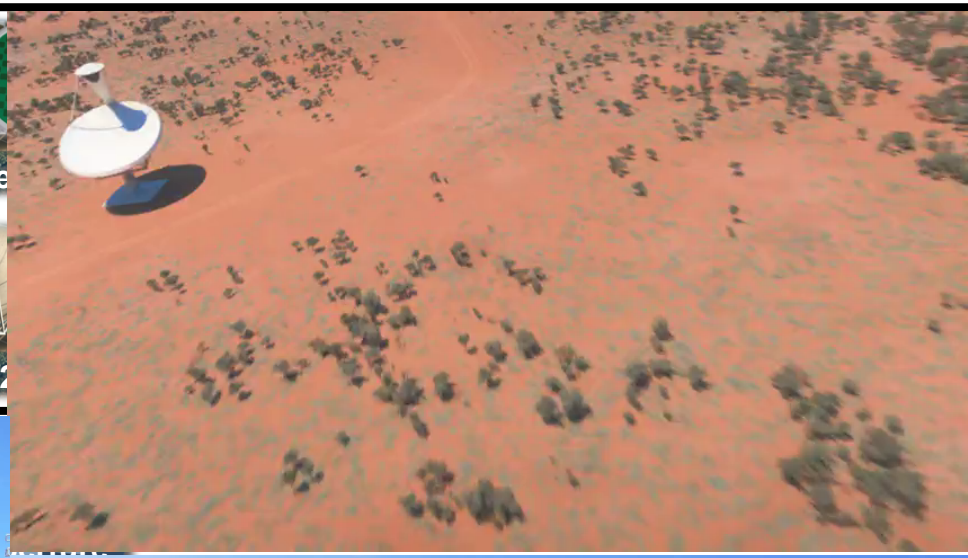


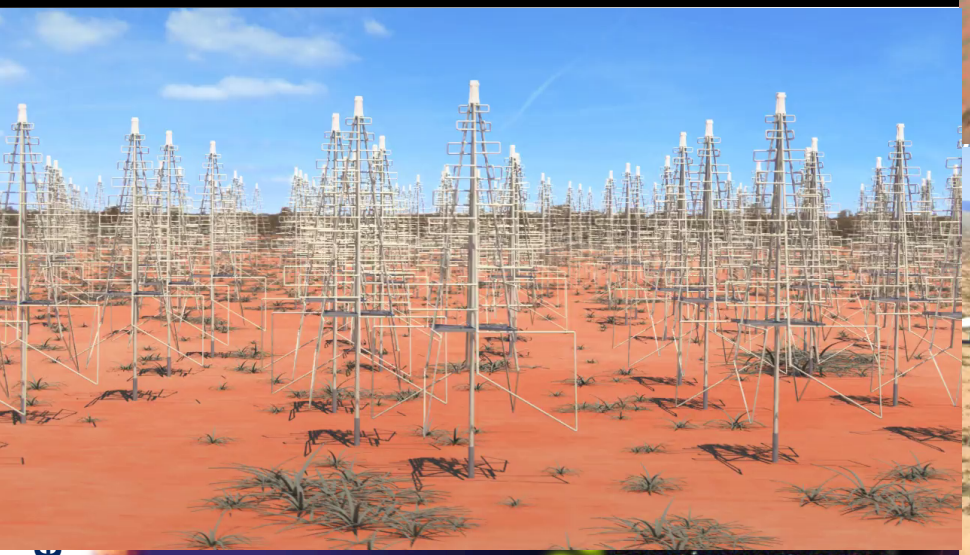
50 MHz 100 MHz 1 GHz 10 GHz

What is the SKA?

Phase I : 2020





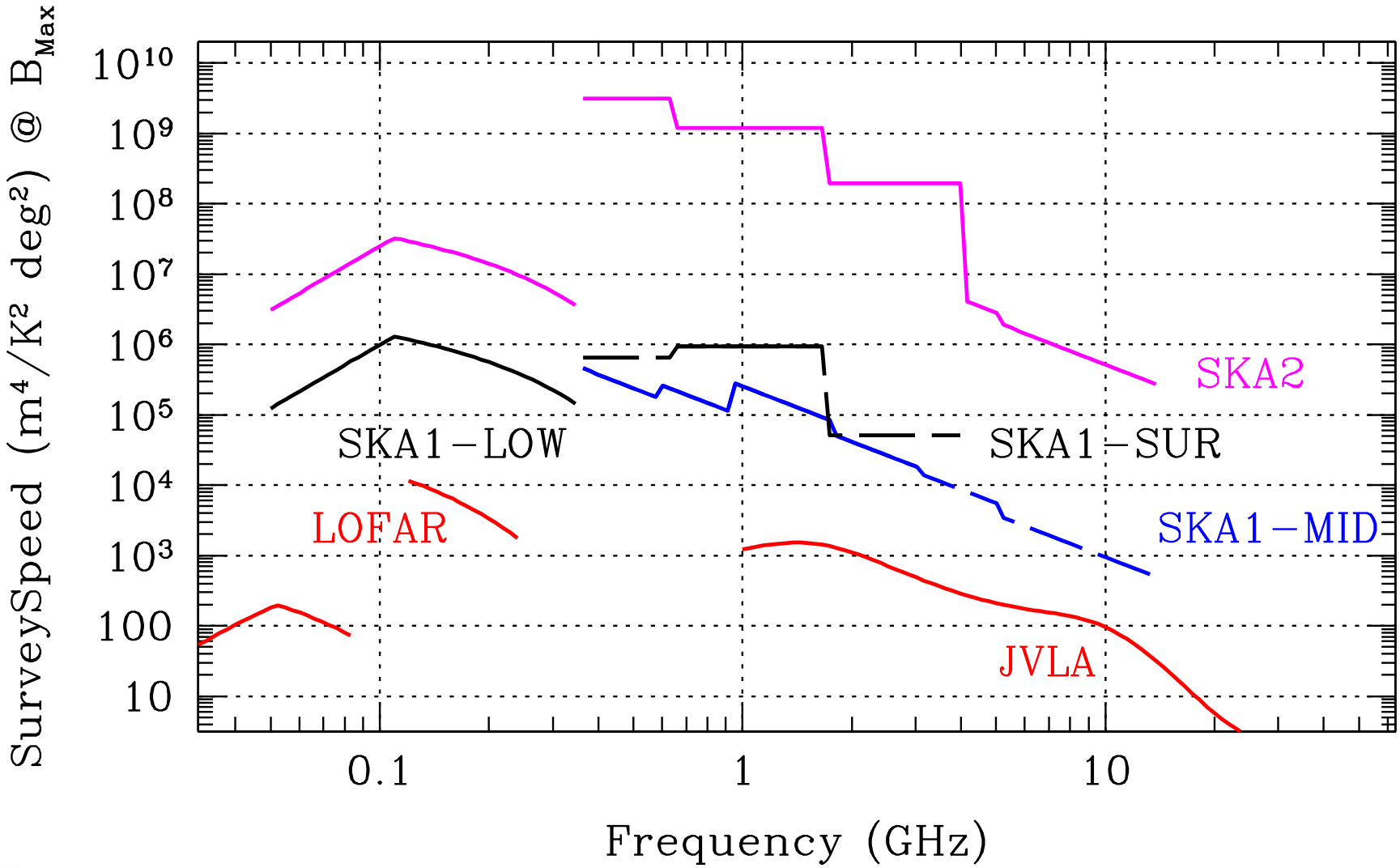


Scie

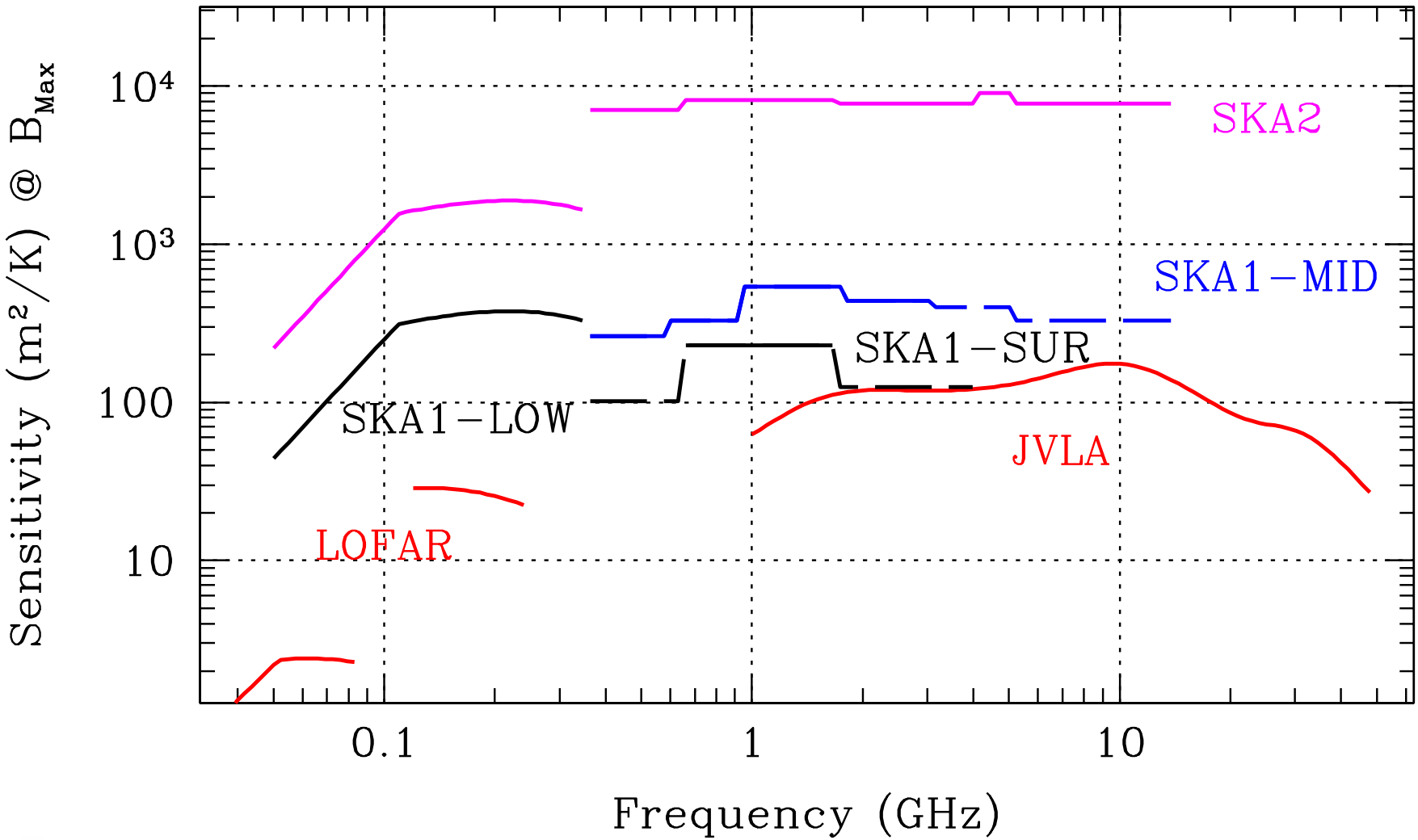
Exploring the Universe with the world's largest radio telescope

50 MHz 100 MHz 1 GHz 10 GHz

Survey speed comparison

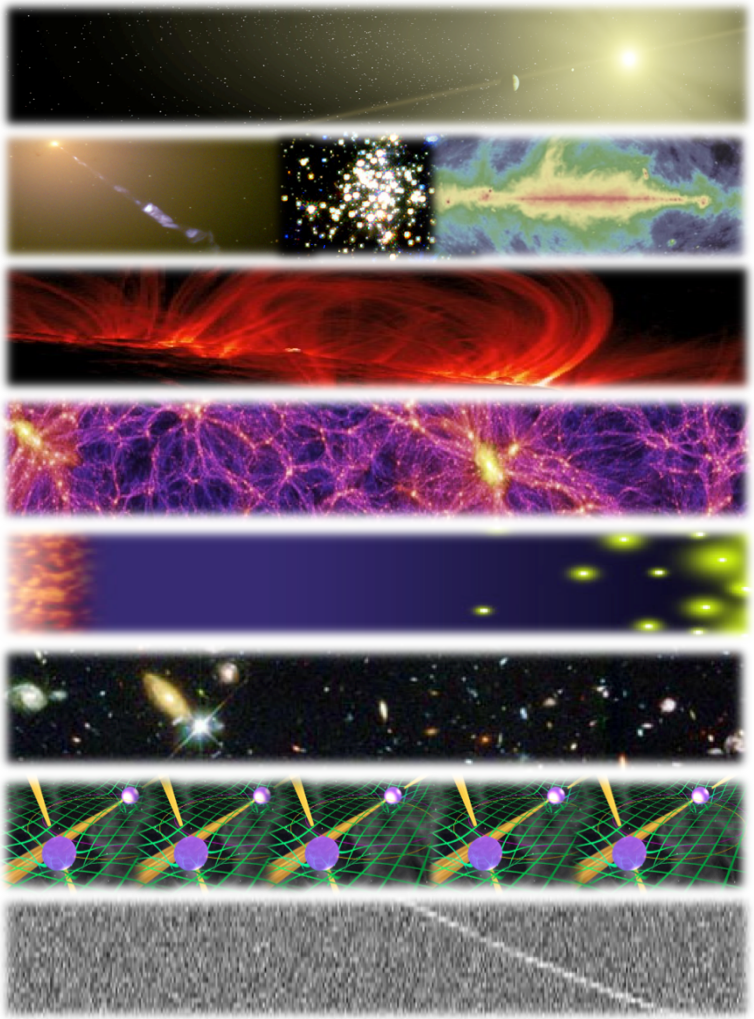


Sensitivity comparison



The SKA Science Working Groups

- **Astrobiology ("The Cradle of Life")**
  - *Project Scientist:* Tyler Bourke
  - *Working Group Chair:* Melvin Hoare
- **Galaxy Evolution – Continuum**
  - *Project Scientist*: Jeff Wagg
  - *Working Group Chairs:* Nick Seymour & Isabella Prandoni
- **Cosmic Magnetism**
  - *Project Scientist:* Jimi Green
  - *Working Group Chairs:* Melanie Johnston-Hollitt & Federica Govoni
- **Cosmology**
  - *Project Scientist:* Jeff Wagg
  - *Working Group Chair:* Roy Maartens
- **Epoch of Reionisation & the Cosmic Dawn**
  - *Project Scientist:* Jeff Wagg
  - *Working Group Chair:* Leon Koopmans
- **Galaxy Evolution – HI**
  - *Project Scientist:* Jimi Green
  - *Working Group Chairs:* Lister Staveley-Smith & Tom Osterloo
- **Pulsars ("Strong field tests of gravity")**
  - *Project Scientist:* Jimi Green
  - *Working Group Chairs:* Ben Stappers & Michael Kramer
- **Transients**
  - *Project Scientist:* Tyler Bourke
  - *Working Group Chairs:* Rob Fender & J.-P. MacQuart



SKA Science

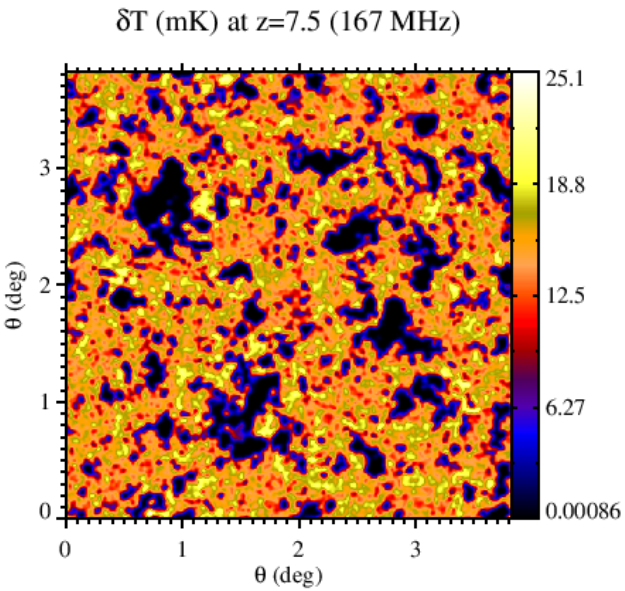
- Release of SKA1 Baseline Design (03/2013)
- Science Assessment Workshops x8 (2013-2014)
  - Posting of all eight Workshop Summaries
- Release of Level 0 Science Requirements (06/2014): https://www.skatelescope.org/home/technicaldatainfo/key-documents/
- Update of SKA1 configurations (05/2014)

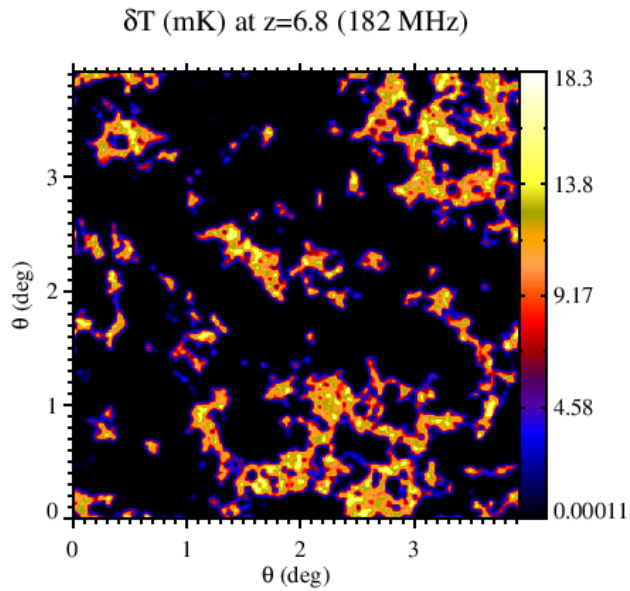
SKA Science

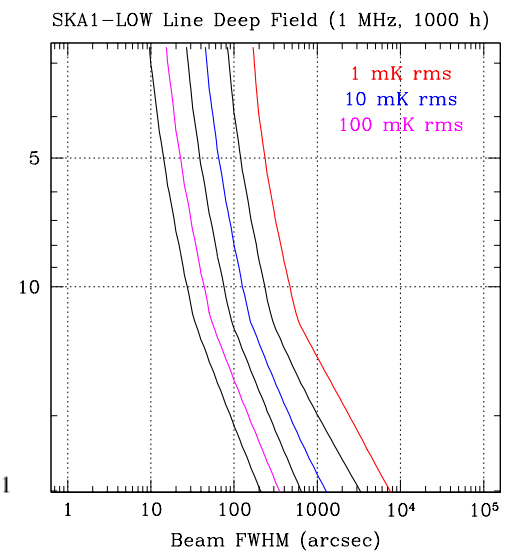
- Strong-field Tests of Gravity with Pulsars and Black Holes
  Phase 1 headline science
- Galaxy Evolution, Cosmology, & Dark Energy
  Phase 1 headline science
- Emerging from the Dark Ages and the Epoch of Reionization
  Phase 1 headline science
- The Cradle of Life & Astrobiology
- The Origin and Evolution of Cosmic Magnetism

With design philosophy of *Exploration of the Unknown*

HI surveys of the EoR/Cosmic-Dawn Universe



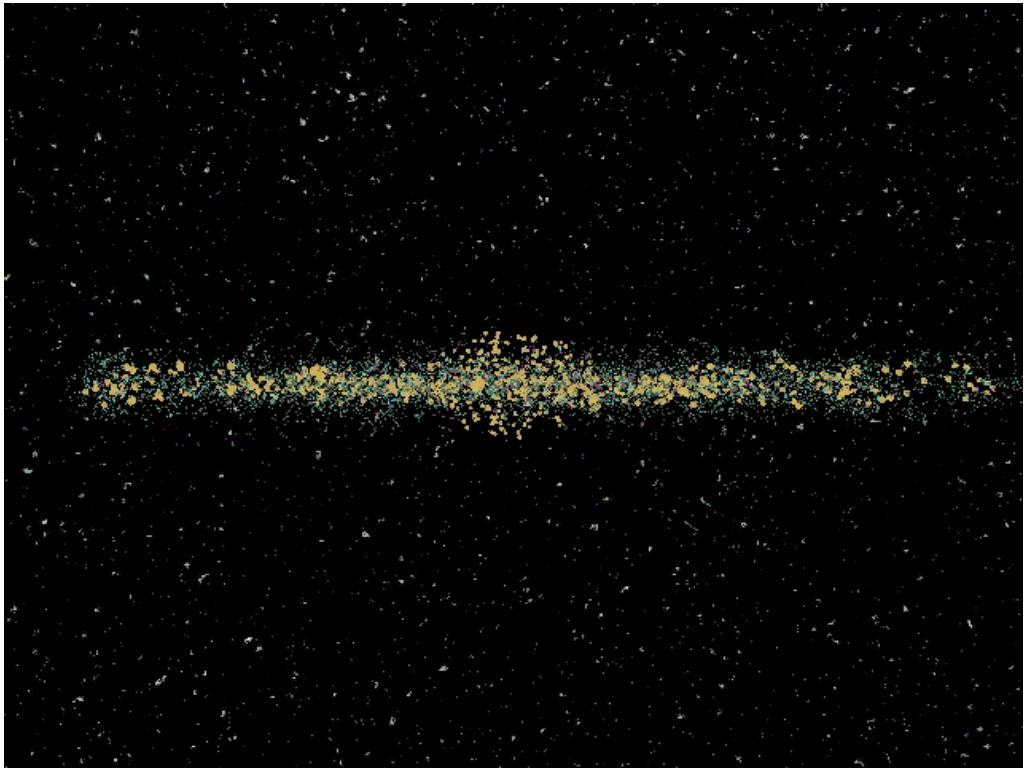


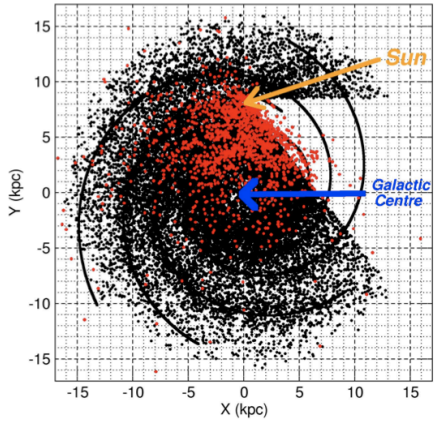


- Detecting EoR structures in imaging mode (as distinct from statistically) on 5 arcmin scales with 1 mK RMS
- Probing the Cosmic Dawn statistically or possibly even imaging in ultra-deep

Finding all the pulsars in the Milky Way…

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

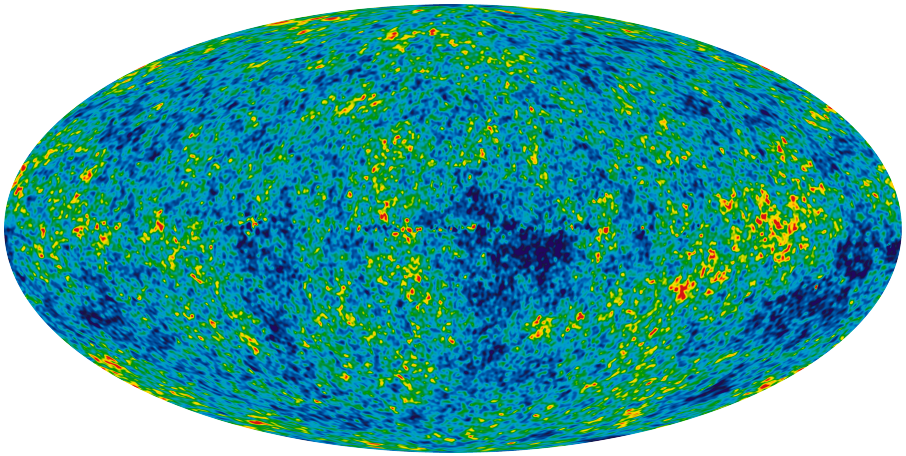


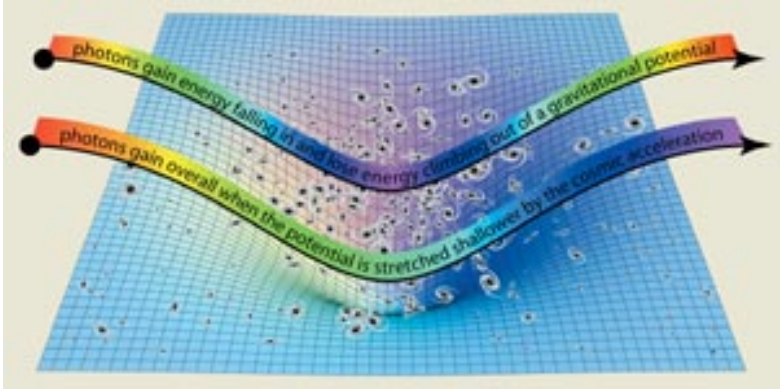


- ~30,000 normal pulsars
- ~2,000 millisecond psrs
- ~100 relativistic binaries
- first pulsars in Galactic Centre
- first extragalactic pulsars

- 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**

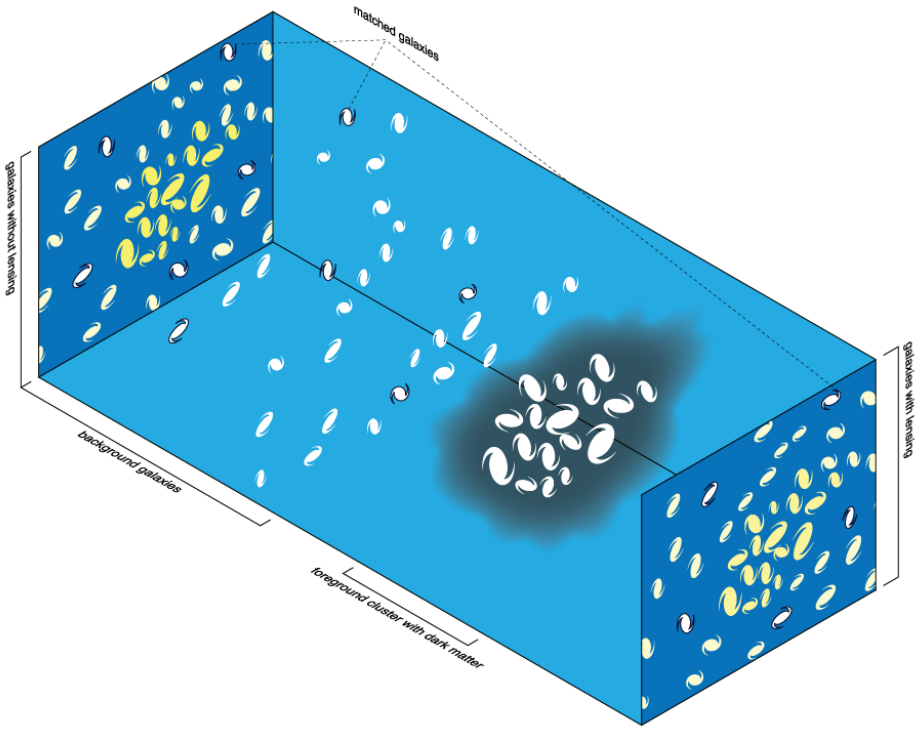
Cosmology with SKA1: Integrated Sachs-Wolfe effect





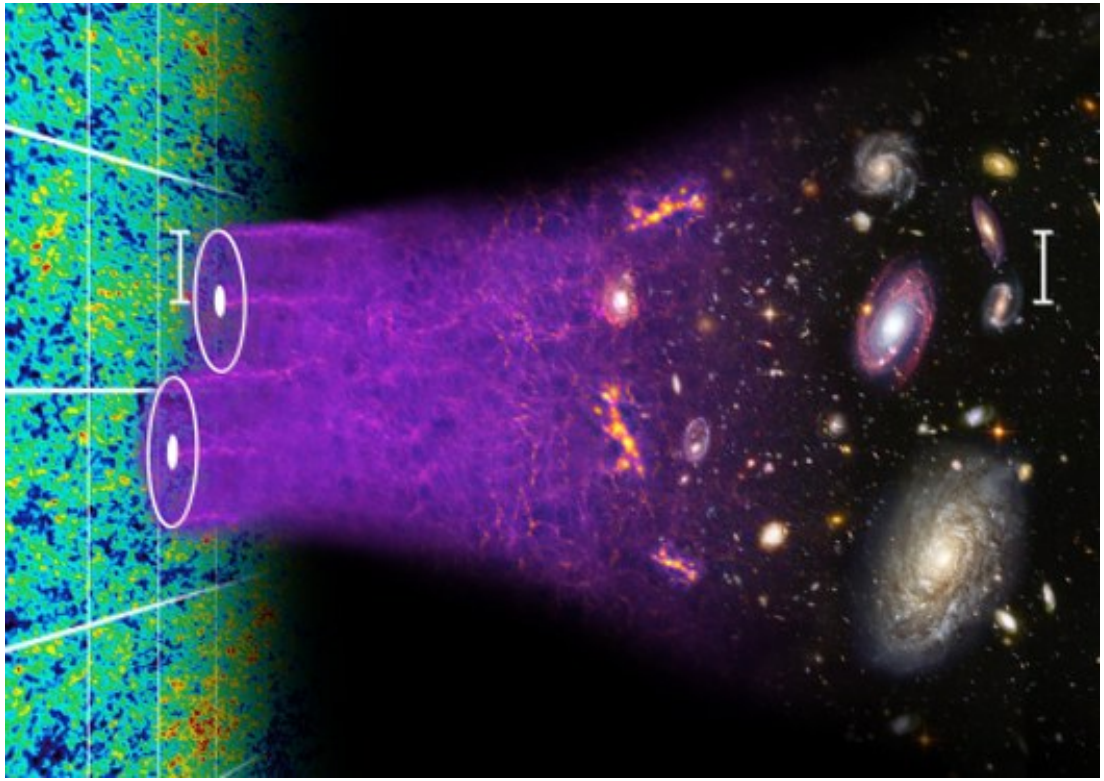
- Constraining non-Gaussianity of primordial fluctuations with the Integrated Sachs-Wolfe effect: correlation of foreground source populations with CMB structures

Cosmology with SKA1: Weak Gravitational Lensing



- Constraining the Dark Energy Equation of State with Weak Gravitational Lensing

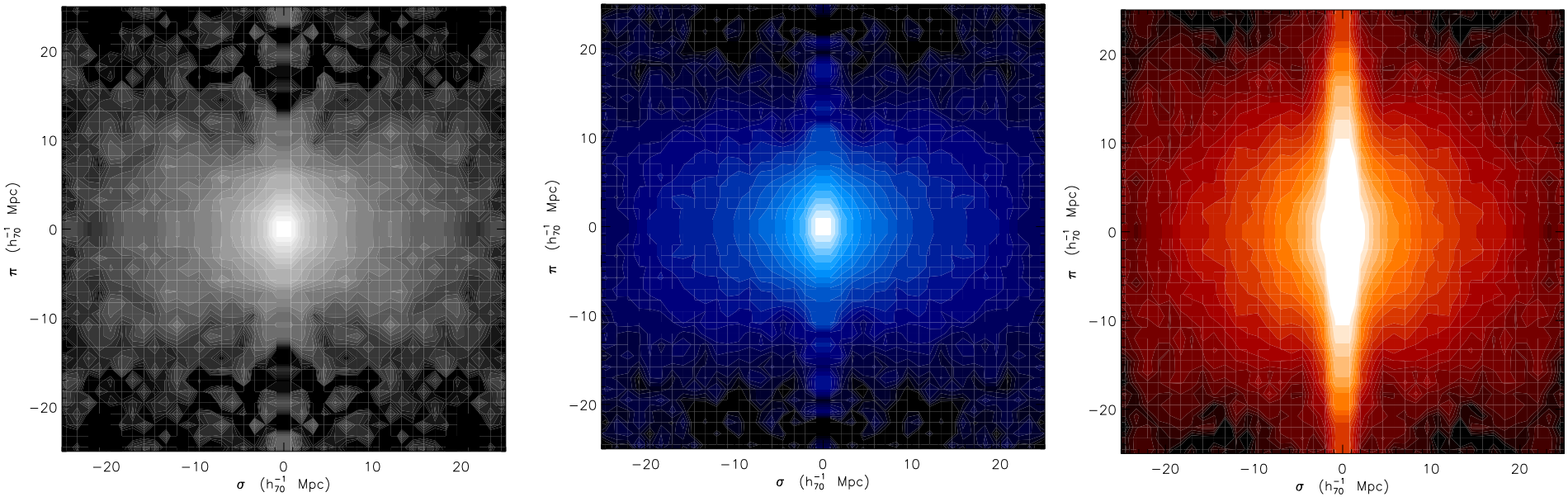
Cosmology with SKA1: Baryon Acoustic Oscillations



(Blake & Moorfield)

- Constraining Dark Energy models with redshift-resolved BAO measurements

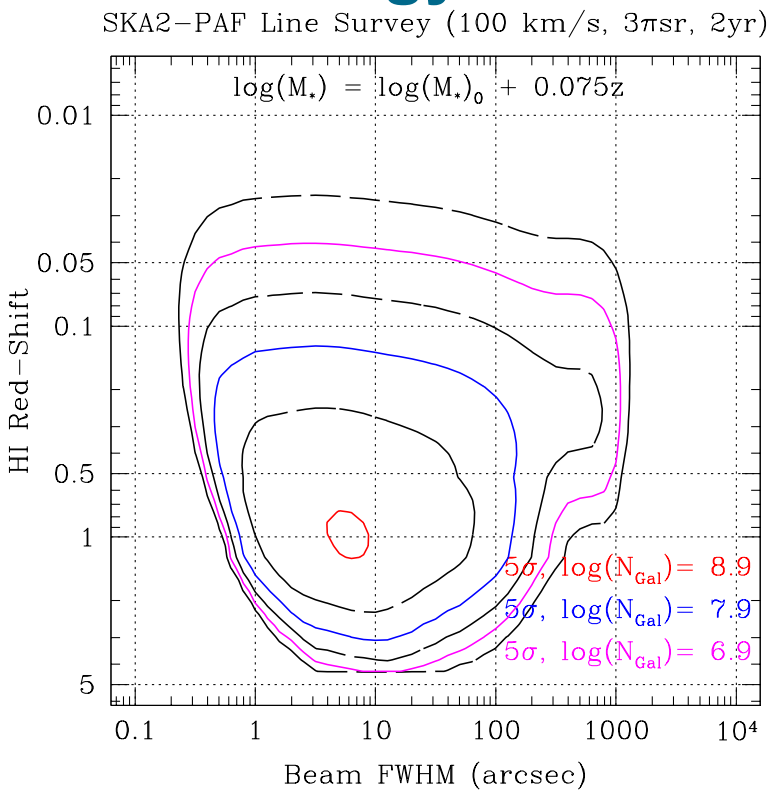
Cosmology with SKA1: complementarity with optical



(Papasterigis et al. 2013) ALFALFA HI versus SDSS blue and red samples

- Correlation functions of HI detections demonstrate much lower bias and excellent prospects for Redshift-space distortion measurements once interesting sample sizes are achieved with SKA1

An SKA2 HI emission survey for precision Cosmology



- Detect $10^{8.9}$ galaxies with <z> ≈ 1, $10^{7.9}$ with <z> ≈ 2
- Compare Euclid (2020+5?) target of 10^8 spectra with <z> ≈ 1
- **SKA2 will provide an unrivaled capability for precision cosmology!**

SKA Science

- Strong-field Tests of Gravity with Pulsars and Black Holes
  - **Unique GR constraints, major contributions in Phase 1 and Phase 2**
- Galaxy Evolution, Cosmology, & Dark Energy
  - **Cutting edge contributions in non-Gaussianity and Dark Energy**
  - **Complementarity to Euclid, LSST in Phase 1 (reduced systematics)**
  - **Unmatched performance in Phase 2 (Billion Galaxy Surveys)**
- Emerging from the Dark Ages and the Epoch of Reionization
  - **Unique EoR imaging capability in Phase 1**
  - **Reaching to Cosmic Dawn in Phase 2**
- The Cradle of Life & Astrobiology
  - **Unmatched performance in Phase 2**
- The Origin and Evolution of Cosmic Magnetism
  - **Unmatched performance in Phase 2**

With design philosophy of *Exploration of the Unknown*

Unmatched prospects (complement to LSST) in Phase 1 and Phase 2

SKA Science Book:
Key Steps

- Mar 21: Notification of provisional authors/presenters
- Mar 28: Draft conference program available
- May 9: Draft chapters due
- May 16: Final program released
- June 8: Conference starts
- August 22: Final chapter submission
  - Review and editing coordinated by SKA Science Team
- End of 2014: Publication of new SKA science book

SKA Science Book:

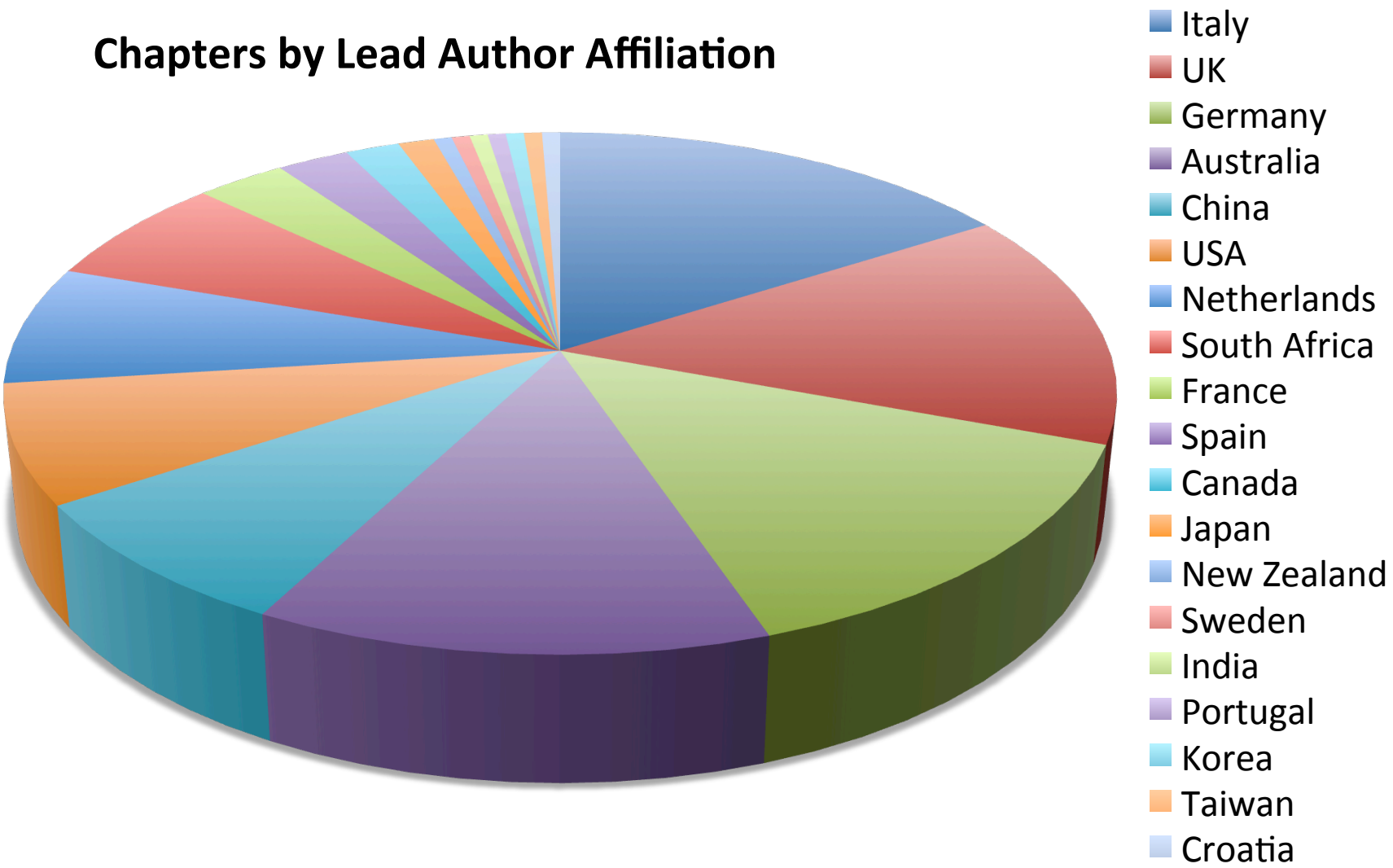
- Meeting Program based on advanced Chapter drafts
- Contributions matched to instrumental capabilities:
  1. SKA1, early deployment phase (50% and up)
  2. Fully specified SKA1
  3. Fully specified SKA2
- 130 self-contained chapters in preparation

SKA Science Book:

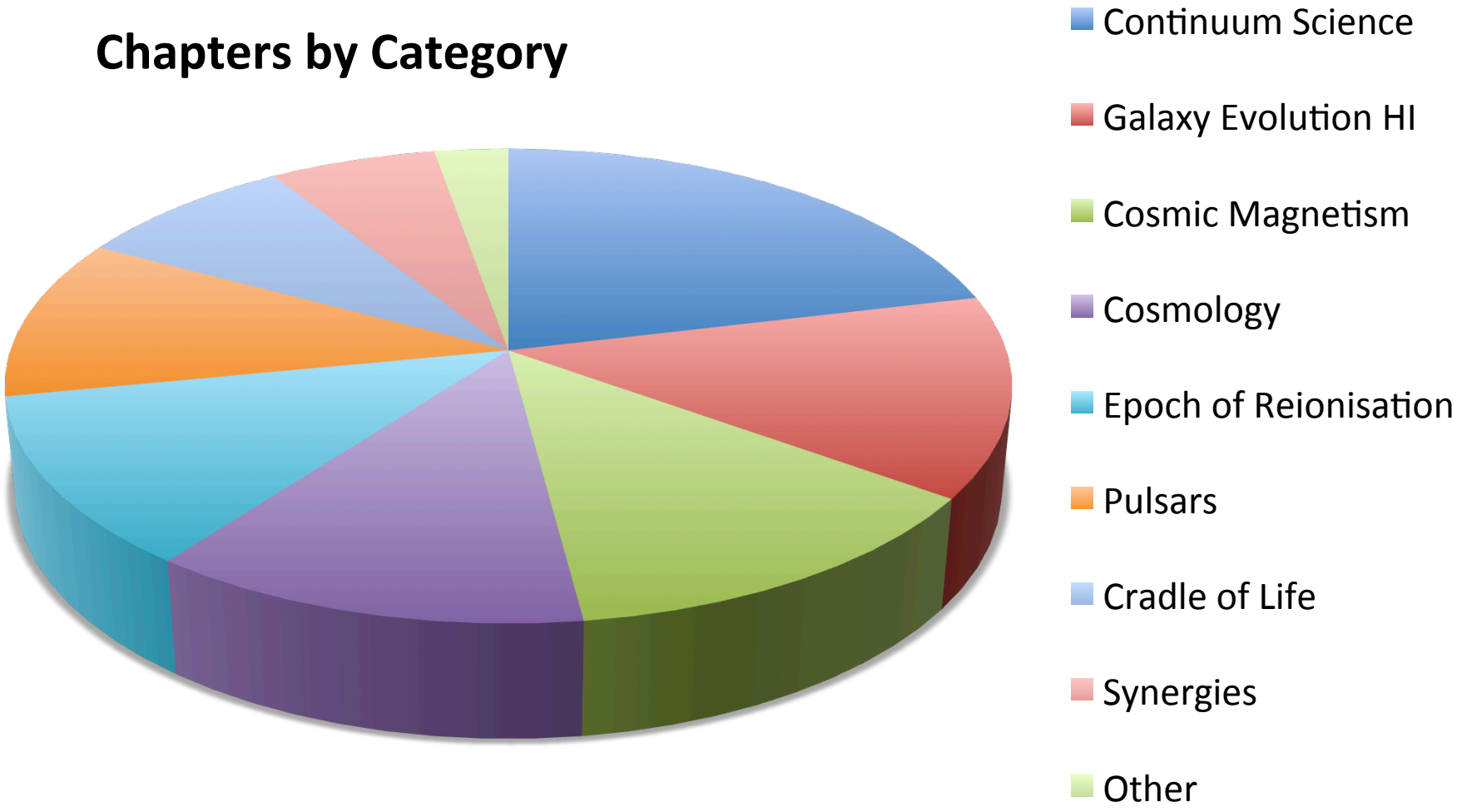
Anticipated Structure

- Overview chapters that focus on highlights and broad areas of major impact:
  - One each for the existing SWGs
  - Likely at least one additional on “Synergies with other Facilities”
- Contributed chapters
  - Regular contributions: ~ 15 pages
  - Short contributions: ~ 8 pages
- Overall correspondence of chapters and talks, but not a strict one-to-one correspondence in either direction

SKA Science Book:



SKA Science Book:



SKA Science: Re-baselining

- Openness and transparency
- Organisation by Science Working Groups
- Representation via SWG Chairs and SKA Member nominees
- Advise SKAO on science impact of viable options
- Public discussion session on Wednesday evening