Science Requirements from the Office Perspective (the Design Reference Mission)

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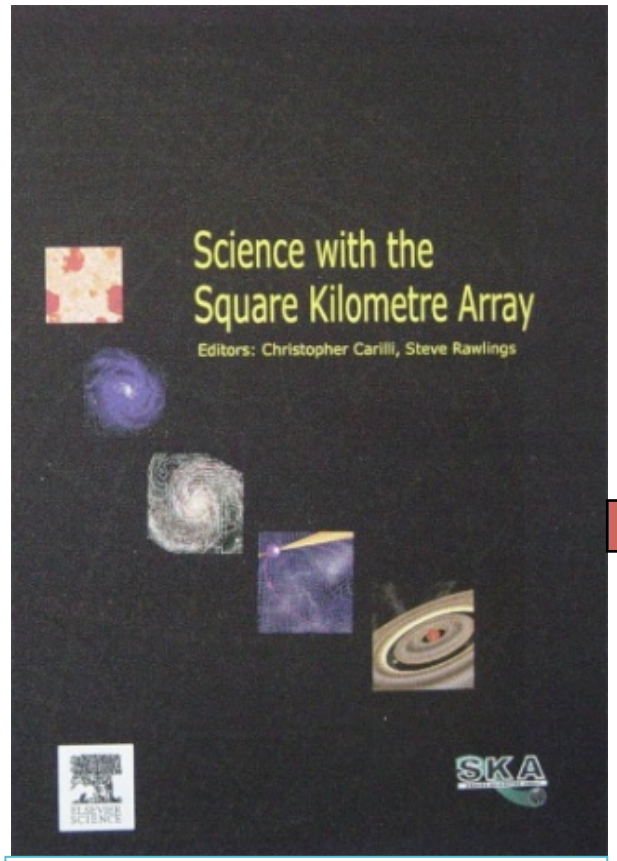
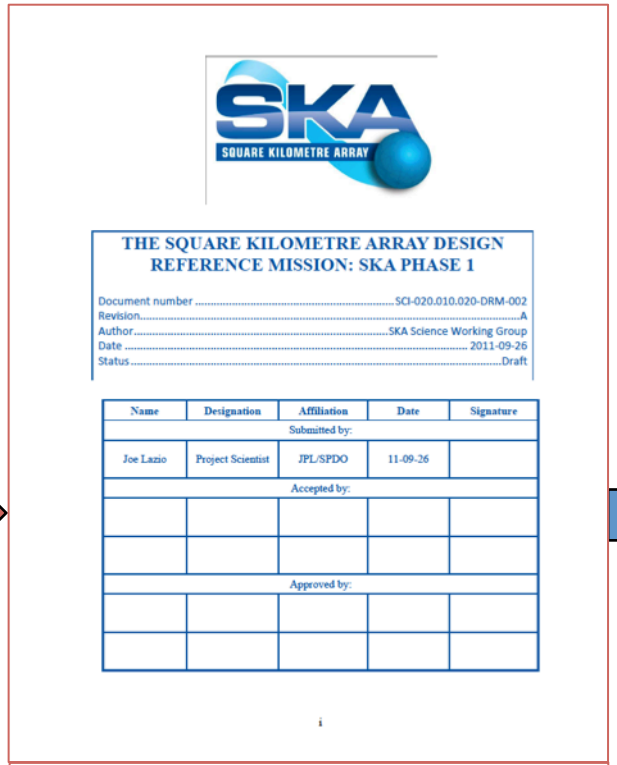
Science Case, DRM, Requirements



Science Case

Lays out **overarching** goals, full suite of science



THE SQUARE KILOMETRE ARRAY DESIGN REFERENCE MISSION: SKA PHASE 1

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Approved by:				

Design Reference Mission

Set of science observations to set **envelope** of science requirements

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SCI-SYSR-0010
SCI-SYSR-0020
…
SCI-S-REQ-0110
SCI-S-REQ-0120
SCI-S-REQ-0130
SCI-S-REQ-0140
SCI-S-REQ-0150
…
SCI-T-REQ-0110
SCI-T-REQ-0120
SCI-T-REQ-0130
SCI-T-REQ-0140
SCI-T-REQ-0150
…
OPS-REQ-0010
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Requirements Document

Input from science, but from other areas as well

The Design Reference Mission: Intro

- Intended to establish a baseline set of observations required to achieve science goals
- Set the “envelope” of possible technical specifications for the telescope
  - Push capabilities of the telescope
- Analogous to similar documents of other large projects:
  - “Science Goals and Technical Requirements” for eVLA
  - ALMA Reference Science Plan
  - JSWT Design Reference Mission
  - LSST Science Requirements Document
  - Pan-STARRS PS1 Design Reference Mission

Design Reference Mission Structure

Chosen to

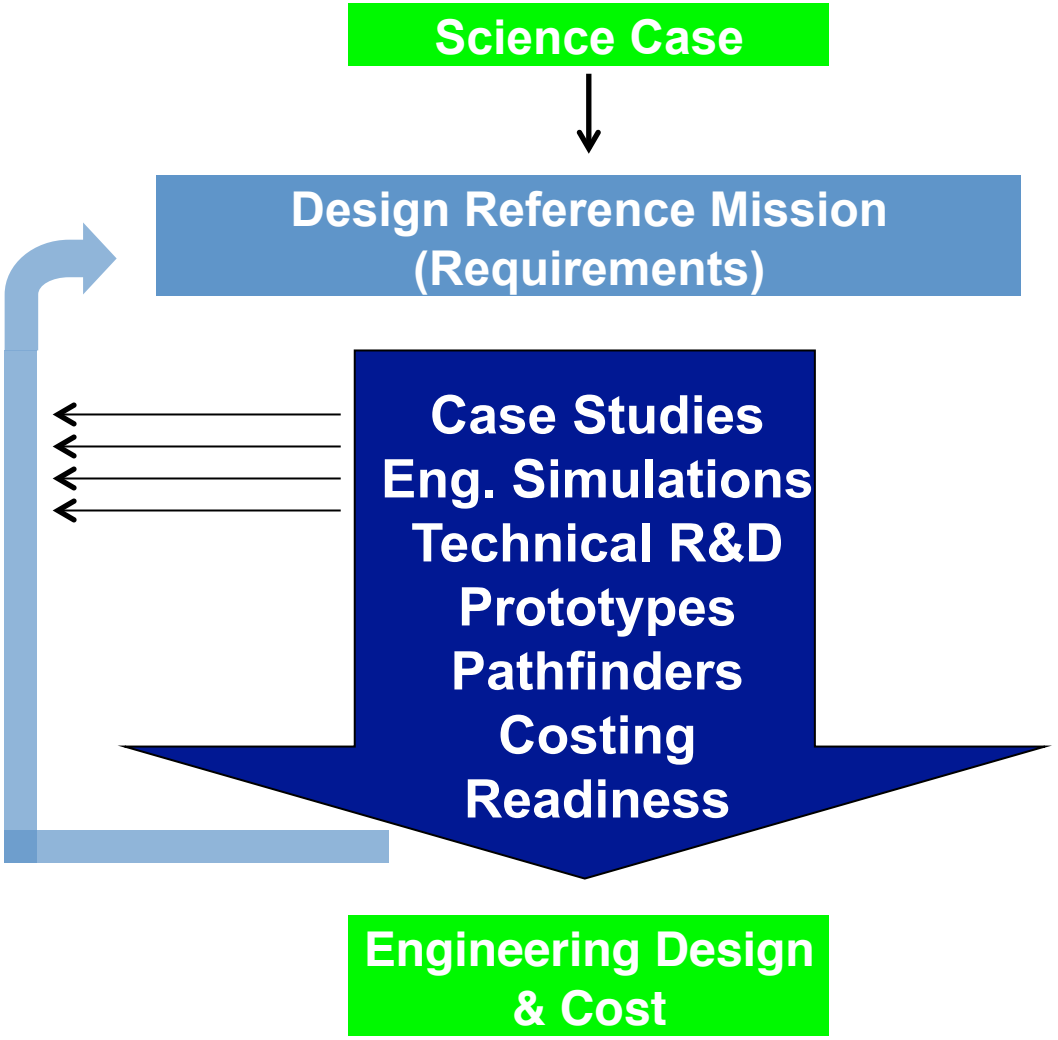
I. Describe fundamental science for the SKA1
II. Identify "envelope" for SKA1 (e.g., frequency coverage)

Chapters

1. Scientific Motivation
2. Observational Summary
3. Scientific Requirements
   What does the Universe control? (e.g., H I mass, gravitational wave amplitude spectrum, …)
4. Technical Requirements
   What do we control? (e.g., A_{eff}, T_{sys}, Ω, ν, baselines, …)
5. Data Products

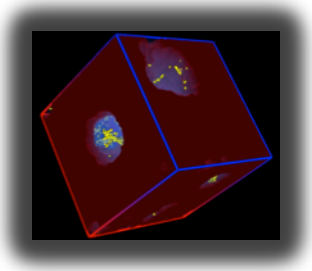
Design Reference Mission Status

- Provides “traceability” or science to technical specifications flowdown
- Version 1.0 is the current for Phase 2
- Version 3.0 is the current for Phase 1
  - Baselined in May 2012



Phase 1 Design Reference Mission: Chapters

2. Probing the Neutral Intergalactic Medium During the Epoch of Reionization
3. Tracking Galaxy Evolution over Cosmic Time via HI Absorption
4. Probing the Epoch of Reionization using the 21cm Forest
5. Pulsar Surveys with Phase 1 of the SKA
6. Pulsar Timing with Phase 1 of the SKA
7. Pulsar Astrometry with Phase 1 of the SKA
8. Gas in Nearby Galaxies
9. Additional Science Capabilities of Phase 1
10. Additional Telescope Considerations: Phase 1 to Phase 2

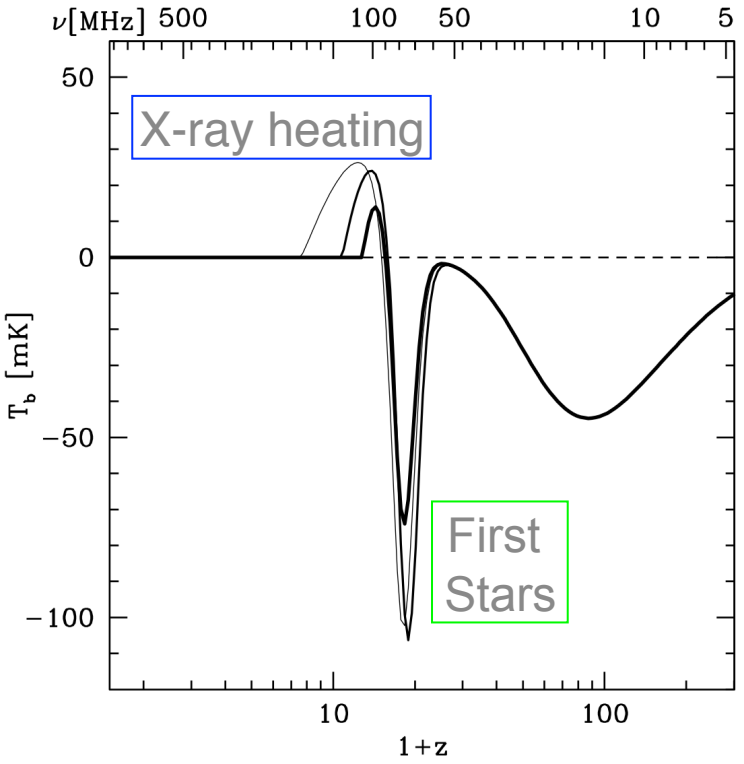


Probing the Neutral Intergalactic Medium During the Epoch of Reionization

Redshift

- *The SKA Phase 1 shall be able to observe the H I line over at least the redshift range of 6–19, with the goal of observing over the redshift range of 6–30.*

- Lower limit set by end of reionization, given by QSO spectra to be z = 6 (Fan et al. 2006)
- Upper limit set by Lyman-α emission from stars (Wouthuysen-Field effect). The absorption feature can be as early as z = 30.



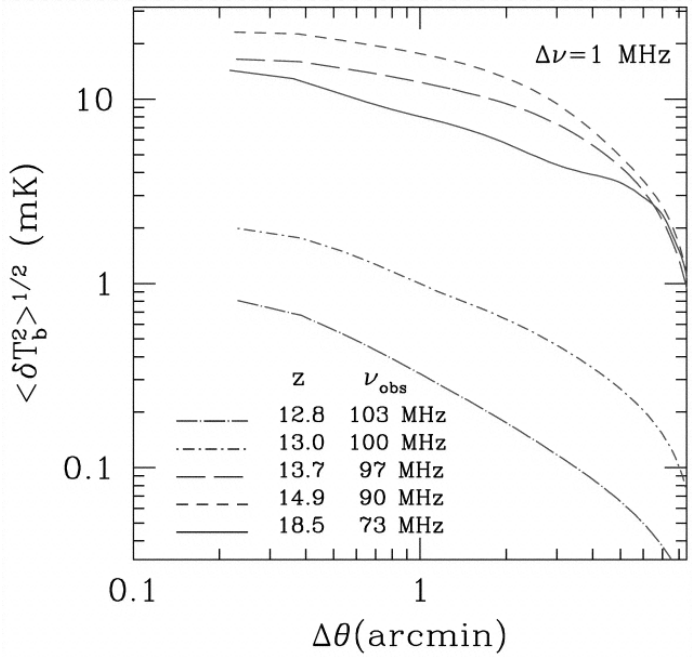
Pritchard & Loeb 2008

Probing the Neutral Intergalactic Medium During the Epoch of Reionization

Sky Brightness Temperature Sensitivity

- *The SKA Phase 1 shall provide a brightness temperature noise level, typically taken as the root-mean-square value, of 1 mK on arcminute angular scales.*

- Models predict a peak in differential brightness temperature of ~ 10 mK over arcminute scales.



Ciardi & Madau 2003

Probing the Neutral Intergalactic Medium During the Epoch of Reionization

Angular Resolution

- *The SKA Phase 1 shall provide an angular resolution at least as high as 1'.*
  - 0.11 to 0.35 Mpc on the sky over z = 6 to 30

Radial Resolution

- *The SKA Phase 1 shall provide a radial resolution over the required frequency range for these observations of 0.1 Mpc.*
  - Match angular resolution

Field of View

- *The SKA Phase 1 shall provide an angular area for analysis sufficiently large to mitigate cosmic variance.*
  - DRM mentions 1 Gpc^3 or an area greater than 5 deg in diameter

Probing the Neutral Intergalactic Medium During the Epoch of Reionization

Scientific Requirements

Parameter	Value
Redshift	6 – 19 (goal 6 – 30)
Sky Brightness Temperature Sensitivity	1 mK
Angular Resolution	1 arcmin
Radial Resolution	0.1 Mpc
Field of View	Sufficient to mitigate cosmic variance, 5 deg^2

Technical Requirements

Parameter	Value	Comment
Frequency Range	70 – 200 MHz (goal 50 – 200 MHz)	Redshift
Frequency Resolution	<100 kHz	Radial Resolution
Maximum Baseline	At least 5km (maybe 50km)	Angular Resolution (Calibration and foreground removal)
Polarization	Full	Calibration and foreground removal
Sensitivity and Integration Time	Aeff/Tsys of 200 to 10,000 m^2 K^{-1} for 1000 hour integration	Reach 1mK sensitivity, depends on smoothing scale and frequency
Imaging Fidelity	Instrumental artefacts less than brightness temp noise level (1 mK)	

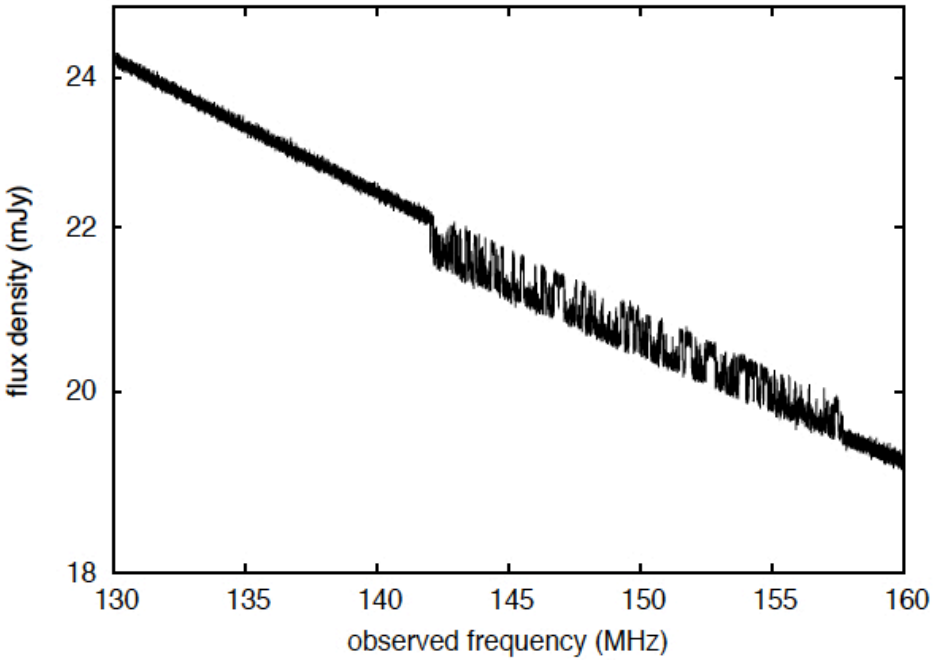
Probing the Epoch of Reionization Using the 21cm Forest

Redshift

- *The SKA Phase 1 shall be able to access the H I line over at least the redshift range of 6 to 20, with the goal of accessing the redshift range of 6 to 30.*

- Lower limit set by end of reionization. Upper limit set by the objective of probing deeply into the epoch of reionization.

- Most distant quasar is at z = 7.085 (Mortlock et al. 2011). Galaxies have been identified with phot-z >10 (Bouwens et al. 2012). GRBs at z = 30 have been discussed (Inoue et al. 2007).

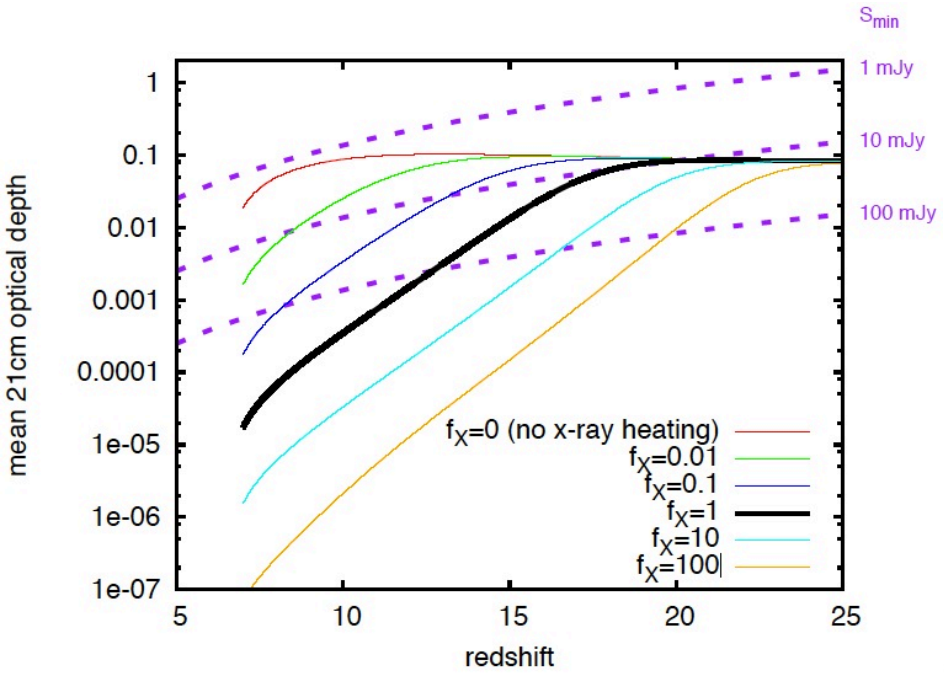


Mack et al. 2011 simulation of Cygnus A at z = 9

Probing the Epoch of Reionization Using the 21cm Forest

Optical Depth

- *The SKA Phase 1 shall be able to detect H I absorption at optical depths of 0.001 or lower.*
  - Estimates of optical depth vary (depends on redshift, state of the gas responsible for absorption) but this allows a range of conditions to be probed



Mack et al. 2012

S_{min} here assumes SKA2 sensitivities and 1 week of (168 hours) integration. Converting to Baseline Design A_{eff} and 1000 hours implies S_{min} * 3.

Probing the Epoch of Reionization Using the 21cm Forest

Velocity Resolution

- *The SKA Phase 1 shall be able to provide a velocity resolution of 0.2 km s^{-1} or better.*
  - Deep absorption features could result from gas having a velocity width of less than a few km s^{-1} (Furlanetto and Loeb 2002)

Sky Coverage

- *The SKA Phase 1 shall be able to access as large a fraction of the sky as feasible, notionally at least 2π steradians.*
  - High redshift radio-loud objects are rare, requiring a large area of sky to be accessible. GRBs can be at any location in the sky.

Probing the Epoch of Reionization Using the 21cm Forest

Scientific Requirements

Parameter	Value
Redshift	6 – 20 (goal 6 – 30)
Optical Depth	0.001
Velocity Resolution	0.2 km s^{-1}
Sky coverage	>2π sr

Technical Requirements

Parameter	Value	Comment
Frequency Range	70 – 200 MHz (goal 50 – 200 MHz)	Redshift coverage
Frequency Resolution	0.1 kHz	Velocity resolution at 150 MHz
Sensitivity	1300 m^2 K^{-1}	Fiducial AGN flux density at z > 7, HI optical depth