Science Requirements from the Office Perspective: The Design Reference Mission

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Science Case, DRM, Requirements, Oh My!

Science Case
Lays out overarching goals, full suite of science

Design Reference Mission
Set of science observations to set envelope of science requirements

Requirements Document
Input from science, but from other areas as well

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
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
  – JSwift Design Reference Mission
  – LSST Science Requirements Document
  – Pan-STARRS PS1 Design Reference Mission
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., $A_{\text{eff}}$, $T_{\text{sys}}$, $\Omega$, $\nu$, baselines, …)
5. Data Products
Design Reference Mission Status

• Provides “traceability” or flow from science to technical specifications

• Version 1.0 is the current for Phase 2

• Version 3.0 is the current for Phase 1
  • Baseline in May 2012

• Phase 1 DRM -> Phase 1 Baseline Design
  - Change process currently being finalised
Phase 1 Design Reference Mission: Chapters

1. Introduction
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
11. Overall Telescope Characteristics
SKA Phase 1 DRM

• SKA1 DRM constrained by Memo 125, SKA1 science priorities:
  – Understanding the role of neutral hydrogen in the universe from the dark ages to the present day (EoR, HI in galaxies)
  – Detecting and timing pulsars in order to test theories of gravity and detect gravitational waves

• Several HI chapter possibilities were discussed:
  – WALLABY like survey in Phase 1 ruled out
  – HI in local galaxies
Gas in Nearby Galaxies

• Science Goals:
  – IGM, low column density environments of galaxies, cold gas accretion onto galaxies
  – Detailed gas physics of star formation

• Similar to THINGS (VLA), HALOGAS (WSRT)

• Large number of galaxies, variety of morphologies and environments
  – 100s of galaxies, each with 30 hours of integration

• Drives sensitivity and frequency resolution at \(~1.4\) GHz
**Linear Resolution**

- *The SKA Phase 1 shall provide a linear resolution of 300 pc at a redshift of 0.02 or distance of 60 Mpc.*

**Redshift**

- *The SKA Phase 1 shall be able to access the H I line over the redshift range of 0 to 0.02.*

**HI Column Density**

- *The SKA Phase 1 shall be able to reach an H I column density of $5 \times 10^{20}$ cm$^{-2}$ at its highest linear resolution within galaxies and $10^{18}$ cm$^{-2}$ at low linear resolution characteristics of galactic scales.*
Velocity Resolution
- The SKA Phase 1 shall provide a velocity resolution of at least 0.5 km s\(^{-1}\).

Area of Regard
- The SKA Phase 1 shall provide the capability to image an area of 500 kpc diameter at a redshift of 0.02 or distance of 60 Mpc, with the goal of providing the capability to image an area of 1 Mpc diameter at a distance of 10 Mpc.
### Gas in Nearby Galaxies

#### Scientific Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear Resolution</td>
<td>300 pc</td>
</tr>
<tr>
<td>Redshift/Distance</td>
<td>0 – 0.02, out to 60 Mpc</td>
</tr>
<tr>
<td>HI Column Density</td>
<td>$5 \times 10^{20}$ cm$^{-2}$ (high linear resolution, ~ 300 pc or better)</td>
</tr>
<tr>
<td></td>
<td>$10^{18}$ cm$^{-2}$ (low linear resolution, ~ 1 kpc)</td>
</tr>
<tr>
<td>Velocity Resolution</td>
<td>0.5 km s$^{-1}$</td>
</tr>
<tr>
<td>Area of Regard</td>
<td>500 kpc at a distance of 60 Mpc</td>
</tr>
</tbody>
</table>

#### Technical Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Range</td>
<td>1390 – 1420 MHz</td>
<td>Redshift range</td>
</tr>
<tr>
<td>Baselines</td>
<td>50 km</td>
<td>Linear resolution</td>
</tr>
<tr>
<td>Spectral Resolution</td>
<td>2 kHz</td>
<td>Velocity Resolution</td>
</tr>
<tr>
<td>Brightness Temperature Sensitivity</td>
<td>200 K for 50 km, 0.3 K for 1.5 km</td>
<td>HI Column Density and Linear Resolution</td>
</tr>
<tr>
<td>Field of View</td>
<td>0.5 deg FWHM</td>
<td>Area of Regard</td>
</tr>
</tbody>
</table>

Exploring the Universe with the world’s largest radio telescope