



**Memo 83**  
**SKA Key Science Requirements Matrix**  
**2006**  
**Prime Science Drivers**  
(V1)

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08/06

## **SKA Key Science Requirements Matrix 2006 Prime Science Drivers**

This document and the associated matrix have been compiled from input from members of the SWG. Both this discussion document and the matrix were updated during 2005 and 2006, as a result of discussions at Key Science workshops and at Pune and Paris. These have created a consolidated description of the SKA key science goal SKA requirements.

### **Background**

In an earlier SKA memo (#29, [www.skatelescope.org](http://www.skatelescope.org)) a simple parameter space analysis was compiled, based on the SKA science case of 1998 (Taylor et al.). As that science case made no prioritisation of the individual goals, all science drivers were treated with equal weighting. By identifying the requirements of the individual science drivers with respect to a wide range of simple specifications (e.g. frequency requirements, requirement for multiple fields of view, continuum or channel sensitivity etc) we illustrated that even a simple analysis could offer insight into the 'best-fit' SKA specification.

Since 1998 the SKA science case has developed markedly – both with the advent of what might be considered far more challenging experiments (e.g. 'Dark Energy' and 'the Epoch of Reionization') and the identification of the 'Key' science drivers: these being the head-line experiments which the SKA would be capable of addressing (Gaensler et al, SKA memo #44).

### **This analysis**

This new analysis has reviewed the parameters in the matrix, using the SKA specification goals set out by Dayton Jones et al (SKA memo #45). This matrix and explanation document build on the content of memo #45 as here we break down the requirements per KSG experiment. We can clearly see where the demanding overall SKA specification originates. An important point to remember is that 4/5 of the "Key Science Goals" are themes, and whilst they collect together highly-related topics, the requirements of their 3 experiments can be radically different – producing an 'SKA specification' that detractors like to quote as being from 'DC to daylight'.

### **The Prime drivers**

At the Pune SKA meeting in November 2005, the SWG discussed the Key Science Projects and set out a list of “Prime Drivers” – the ‘vital’ or headline parts of the key science projects - as being

### **The Cradle of Life**

Planet formation in Protoplanetary disks

### **Strong field tests of gravity using pulsars & black holes**

tests of gravity using binary pulsars with NS & BH companions  
nHz gravitational waves using MSP timing array

### **Cosmic Magnetism**

RM grid

### **Galaxy Evolution & Cosmology**

Galaxy evolution (emission to  $z \sim 3$ , abs  $z > 3$ )  
Dark energy (HI baryon oscillations)

### **Probing the Dark Ages**

Map EoR from redshifted HI

### **& New Discovery Space**

These experiments are highlighted in yellow in the matrix.

### **Description of matrix values for each experiment**

This section defines the columns/sections and values adopted in the shorter KSG science requirement matrix.

#### **1 SKA Frequency range requirements**

Shows the frequency range necessary for the experiment. Values in brackets show the useful, but not critical frequency range.

#### **2. Beta**

The instantaneous fractional bandwidth coverage at the mid frequency.

#### **3. FOV**

The continuous FOV size (not necessarily for imaging).

#### **4. Spatial Resolution**

The angular resolution required to achieve the science goal.

#### **5. Maximum baseline**

## **6. Dynamic range**

The dynamic range requirement selected from one of 3 values:

Superb i.e. =>  $10^{**7}$

Good,  $\sim 10^{**6}$

Moderate – around  $10^{**4}$  to  $10^{**5}$

## **7. Signal to noise ratio requirement**

## **8. # separate FOVs (multi-field of view requirement)**

The number of separate FOVs required at the full sensitivity of the SKA, chosen from Y – separate FOVs are necessary for the experiment, with number in ()'s being the minimum number required

N – not a requirement to achieve experiment, but number in () shows useful number if they are available.

## **9. Polarisation requirements**

## **10. sub array utility**

## **11. Sky area to be covered in survey/experiment**

## **12. strategy of the experiment**

## **13. Critical requirements for the experiment**

Here we list the 'show stoppers' for the experiment – if there are any. These comments and their justification should be in the accompanying document which captures this detail.

## **14. Total observing time considerations**

## **15. Other comments**

Anything else which critically drives the SKA spec for that experiment. This is probably a redundant column and may not be kept. These comments should be kept in the text document for the KSG as well.

Note: Total power calibration added March 2006 following comment from Jill Tarter to Peter Hall. Probably needs to be  $\sim 1\%$  for surveys to be matched across the sky.

	C	E	F	G	H	I	J	K	L	M	N	O	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	
1	17-Jul-06	Frequency Coverage											FOV	Resolution	Baseline	Dynamic Range	S/N	Calibration	Multi-field							
2	<b>SKA Key Science Projects (KSP) 2005/6</b>	60-100 MHz	100-200 MHz	200-400 MHz	400-1000 MHz	1-2 GHz	2-4 GHz	4-10 GHz	10-20 GHz	20-35 GHz		Beta (simultaneous fractional bandwidth coverage)	Instantaneous FOV	resolution at key survey frequency	Maximum baseline assuming reskey freq in prev column	S>= 10 <sup>-7</sup> M= 10 <sup>-4</sup> -10 <sup>-5</sup>	S/N	total power calibration	Y/N separate FOVs necessary for expt (0 shows required (Y) or useful (N) number)	Polarisation	sub array useful (Y/N)?	sky area that needs to be covered	strategy			
3	<b>The cradle of life</b>																									
4	Planet formation in Protoplanetary Disks - millarcsecond imaging of YSOs in nearby molecular clouds											10 - 35 GHz	>0.1	sw arcsec - targeted c	2 mas at 20 GHz	1000km	good	tdb	N any							
5	SETI observations of stellar systems within FOV of other programs											1 - 25 GHz	0.2	1 sq deg	n/a	n/a	unimportant			N any						
6	Astrochemistry mini-surveys of nearby molecular clouds for bio molecular lines											1 - 35 GHz	0.04	0.5 - 1 sq deg	100 mas at 10 GHz	60 km	good			N any						
7																										
8	<b>Strong field tests of gravity using pulsars &amp; black holes</b>																									
9	<b>Pulsars - tests of gravity using binary pulsars w NS &amp; BH companions</b>																									
10	- survey of galactic plane & globular clusters											1-2 GHz (0.5 - 3 GHz)	20%	1 sq deg	full FOV pixelization form N beams per FOV	compact core (few km)	NA			N	dual - total I	No	globular clusters, longer baselines: strong pulsars can use sub-arrays.	2 surveys may be needed for confirmation of pulsar candidates		
11	- timing follow-up											1-2 GHz (0.5 - 3 GHz)	20%	1 sq deg		200 km	NA		Y/S	dual - total I	Yes, sometim	clusters,				
12	- high precision timing											0.5 - 3 GHz	20%	single source	NA	at can be phas	NA		N*	full Stokes, hi	Yes, sometim	single targets	FOV useful to achieve	time at least weekly, for many years. Multi		
13	- astrometry of pulsars											3 & 8 GHz	20%	single source	1 mas at 5 GHz	6000 km	moderate		N	total I	No	single targets	gated correlations synchronous with pulse periods			
14	<b>Pulsars - nHz gravitational waves using MSP timing array</b>																									
15	- survey of galactic plane & globular clusters											1-2 GHz (0.5 - 3 GHz)	20%	1 sq deg	full FOV pixelization form N beams per FOV	compact core (few km)	NA			N	dual - total I	No	globular clusters, 1000 sq deg of pulsar candidates	2 surveys may be needed for confirmation of pulsar candidates		
16	- timing follow-up											1-2 GHz (0.5 - 3 GHz)	20%	as large as possible		200 km	NA		Y/S	dual - total I	Yes, sometim	clusters,	longer baselines: strong pulsars can use sub-arrays.			
17	- high precision timing											0.5 - 3 GHz	20%	single source	NA	at can be phas	NA		N*	full Stokes, hi	Yes, sometim	single targets	FOV useful to achieve	time at least weekly, for many years. Multi		
18	- astrometry of pulsars											3 & 8 GHz	20%	single source	1 mas at 5 GHz	6000 km	moderate		N	total I	No	single targets	gated correlations synchronous with pulse periods			
19	<b>Pulsars - in SgrA* star cluster</b>																									
20	Strategy - survey GC											9 - 15 GHz		1 sq deg	NA pixel	n/a	n/a			No	total I	N	GC only	high freqs to combat scattering		
21	- followup & time GC pulsars											9 - 15 GHz		single targeted sources	NA	n/a	n/a			No	full stokes	N	single pointing			
22																										
23	<b>The origin &amp; evolution of cosmic magnetism</b>																									
24	<b>The origin &amp; evolution of cosmic magnetism: All-sky rotation measure survey</b>																									
25	- Map RM grid											1.4 GHz		1 sq deg	500 mas	450 km	moderate	10 across BW		N any	Y - vg					
26	- deep fields: Stokes I imaging v faint unres synch extragal sources											1.4 GHz		~10 arcmin sq(?)	500 mas	100 km	good	3 across BW		N any	Y - vg					
27	- polarisation silhouettes											500 MHz - 10 GHz		1 sq deg	100 mas at 1.4 GHz	450 km	moderate	10 across BW		N any	Y - vg					
28	- tomography											500 MHz - 1.5 GHz		1 sq deg	1 arcsec at 700 MHz	180 km	moderate	5 across BW		N any	Y - vg					
29	- deep polarisation imaging - Stokes Q & U imaging of diffuse ISM & galaxies											5 - 10 GHz		0.1 sq deg	100 mas at 5 GHz	125 km	moderate	5 across BW		N any	Y - vg					
30																										



	C	AD	AE	AF
1	17-Jul-06			
2	<b>SKA Key Science Projects (KSP) 2005/6</b>	Critical requirements for experiment	Total observing time (& assumptions)	Other comments
3	<b>The cradle of life</b>			
4	Planet formation in Protoplanetary Disks - milliarsecond imaging of YSOs in nearby molecular clouds			
5	SETI observations of stellar systems within FOV of other programs	~10**10 channels, total Power, multiple beams per FoV useful		
6	Astrochemistry mini-surveys of nearby molecular clouds for bio molecular lines			
7				
8	<b>Strong field tests of gravity using pulsars &amp; black holes</b>			
9	Pulsars - tests of gravity using binary pulsars w NS & BH companions			
10	- survey of galactic plane & globular clusters			
11	- timing follow-up			
12	- high precision timing	sampling time at least 0.2 microsec. All observations on-axis		
13	- astrometry of pulsars			
14	Pulsars - nHz gravitational waves using MSP timing array			
15	- survey of galactic plane & globular clusters			
16	- timing follow-up			
17	- high precision timing	sampling time at least 0.2 microsec. All observations on-axis		
18	- astrometry of pulsars			
19	Pulsars - in SgrA* star cluster			
20	Strategy - survey GC			Probably use ~1/4 of the SKA, so sub-arraying to cover all sky would be efficient
21	- followup & time GC pulsars			
22				
23	<b>The origin &amp; evolution of cosmic magnetism</b>			
24	The origin & evolution of cosmic magnetism: All-sky rotation measure survey			
25	- Map RM grid	polarisation purity across FOV & BW	~ 1 yr (done with HI & continuum surveys)	
26	- deep fields: Stokes I imaging v faint unres synch extragal sources	polarisation purity across FOV & BW	~ 1 yr (done with HI & continuum surveys)	
27	- polarisation silhouettes	polarisation purity		
28	- tomography	polarisation purity across FOV & BW		
29	- deep polarisation imaging - Stokes Q & U imaging of diffuse ISM & galaxies	polarisation purity across FOV		
30				

	C	AD	AE	AF
1	17-Jul-06			
2	<b>SKA Key Science Projects (KSP) 2005/6</b>	Critical requirements for experiment	Total observing time (& assumptions)	Other comments
31	<b>Galaxy evolution &amp; cosmology</b>			
32	Evolution of gas in galaxies (HI) - HI survey for evolution (emission to z~3, abs > 3)			
33	Dark Energy (HI baryon oscillations) - survey HI, determine mass distr			
34	SFR in galaxies & dark matter from weak lensing (radio continuum) SKA radio sk			
35	H0 from masers - Spectroscopic monitoring & mapping	8000km baseline		
36				
37				
38	<b>Probing the dark ages</b>			
39	Map EoR from redshifted HI - all-sky surveys deep z~19 to z~6 EoR			
40	First SF from CO			
41	Strategy - find/trace 1-0 CO transitions in gals at z~10			
42	- detail map CO in high-z SF			
43	First AGN from continuum surveys			
44	- nanoJy small area survey			
45	- all sky 1microJy survey (all-sky map)			
46	- detect first AGN (select from all-sky map)			
47				