SKA Key Science Project Workshop

Cosmology Key Science Projects Discussion Summary

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on behalf of the Cosmology SWG

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Participants of the Discussion at this Workshop

BACON, David (U Portsmouth)

BATTYE, Richard (U Manchester)

BROWN, Michael (U Manchester)

BULL, Philip (U of Oslo)

CHEN, Xuelei（NAOC） Co-Chair

JARVIS, Matt (U Oxford)

KLOECKNER, Hans-Rainer (MPIfR)

KUNZ, Martin （U of Geneva)

MAARTENS, Roy (U West Cape)

METCALF, R. Benton (U Bologna）

MOODLEY, Kavilan （U Kwazulu-Natal)

PATEL, Prina (U West Cape)

SANTOS, Mario (U West Cape) Co-Chair

SCARAMELLA, Roberto (INAF−Rome Obs)

YAMAUCHI, Daisuke (U Tokyo)

KSPs in the cosmology community

- The Cosmology SWG currently have 72 members
- 21 Chapters in Advancing Astrophysics with the Square Kilometre Array

Session 2: Cosmology

Overview of Cosmology with the SKA PoS(AASKA14)016 pdf	*R. Maartens, F.B. Abdalla, M. Jarvis and M.G Santos*
Cosmology from HI galaxy surveys with the SKA PoS(AASKA14)017 pdf	*F.B. Abdalla, P. Bull, S. Camera, A. Benoit Levy, B. Joachimi, D. Kirk, H.R. Kloeckner, R. Maartens, A. Raccanelli, M.G Santos and G.B. Zhao*
Cosmology with SKA Radio Continuum Surveys PoS(AASKA14)018 pdf	*M. Jarvis, D. Bacon, C. Blake, M. Brown, S. Lindsay, A. Raccanelli, M. Santos and D.J. Schwarz*
Cosmology from a SKA HI intensity mapping survey PoS(AASKA14)019 pdf	*M. Santos, P. Bull, D. Alonso, S. Camera, P. Ferreira, G. Bernardi, R. Maartens, M. Viel, F. Villaescusa-Navarro, F.B. Abdalla, M. Jarvis, R.B. Metcalf, A. Pourtsidou and L. Wolz*
Cross correlation surveys with the Square Kilometre Array PoS(AASKA14)020 pdf	*D. Kirk, F.B. Abdalla, A. Benoit Levy, P. Bull and B. Joachimi*
HI galaxy simulations for the SKA: number counts and bias PoS(AASKA14)021 pdf	*M. Santos, D. Alonso, P. Bull, M.B. Silva and S. Yahya*
Weak gravitational lensing with the Square Kilometre Array PoS(AASKA14)023 pdf	*M. Brown, D. Bacon, S. Camera, I. Harrison, B. Joachimi, R.B. Metcalf, A. Pourtsidou, K. Takahashi, J. Zuntz, F.B. Abdalla, S. Bridle, M. Jarvis, T. Kitching, L. Miller and P. Patel*
Measuring baryon acoustic oscillations with future SKA surveys PoS(AASKA14)024 pdf	*P. Bull, S. Camera, A. Raccanelli, C. Blake, P. Ferreira, M. Santos and D.J. Schwarz*
Cosmology on the Largest Scales with the SKA PoS(AASKA14)025 pdf	*S. Camera, A. Raccanelli, P. Bull, D. Bertacca, X. Chen, P. Ferreira, M. Kunz, R. Maartens, Y. Mao, M. Santos, P.R. Shapiro, M. Viel and Y. Xu*
Real time cosmology - A direct measure of the expansion rate of the Universe with the SKA PoS(AASKA14)027 pdf	*H.R. Kloeckner, D. Obreschkow, C. Martins, A. Raccanelli, D. Champion, A.L. Roy, A. Lobanov, J. Wagner and R. Keller*
Weak Lensing Simulations for the SKA PoS(AASKA14)030 pdf	*P. Patel, I. Harrison, S. Makhathini, F.B. Abdalla, D. Bacon, M. Brown, M. Jarvis, O. Smirnov and I. Heywood*
Measuring redshift-space distortion with future SKA surveys PoS(AASKA14)031 pdf	*A. Raccanelli, P. Bull, S. Camera, C. Blake, P. Ferreira, R. Maartens, M. Santos, P. Bull, D. Bacon, O. Dore, P. Ferreira, M.G Santos, M. Viel and G.B. Zhao*
Testing foundations of modern cosmology with SKA all-sky surveys PoS(AASKA14)032 pdf	*D.J. Schwarz, D. Bacon, S. Chen, C. Clarkson, D. Huterer, M. Kunz, R. Maartens, A. Raccanelli, M. Rubart and J.L. Starck*
Topology of neutral hydrogen distribution with the Square Kilometre Array PoS(AASKA14)033 pdf	*Y. Wang, Y. Xu, F. Wu, X. Chen, X. Wang, J. Kim, C. Park, K.G. Lee and R. Cen*
Cosmology with galaxy clusters: studying the Dark Ages and the Epoch of Reionization in the SKA era PoS(AASKA14)034 pdf	*S. Colafrancesco, P. Marchegiani and M.S. Emritte*
Foreground Subtraction in Intensity Mapping with the SKA PoS(AASKA14)035 pdf	*L. Wolz, F.B. Abdalla, D. Alonso, C. Blake, P. Bull, T.C. Chang, P. Ferreira, C.Y. Kuo, M. Santos and J.R. Shaw*
Model-independent constraints on dark energy and modified gravity with the SKA PoS(AASKA14)165 pdf	*G. Zhao, D. Bacon, R. Maartens, M. Santos and A. Raccanelli*
Stacking of SKA data: comparing uv-plane and and image-plane stacking PoS(AASKA14)168 pdf	*K.K. Knudsen, L. Lindroos, W.H.T. Vlemmings, J.E. Conway and I. Marti-Vidal*

Cosmology Key Science Projects

- wiki: http://skacosmology.pbworks.com/

- prior to the meeting, 11 possible KSP ideas were discussed on the wiki, some were concerned with specific science cases, some with data analysis technique, some on specific survey. Combined into 5 KSPs at the start of this workshop:

Cosmology with a Continuum Survey
Galaxy Weak Lensing Survey
Cosmology with HI Galaxy Survey
HI Intensity Mapping Survey
Real Time Cosmology

Organization of Key Science Projects

- The KSPs should revolve around major data analysis/calibration efforts with requirements for large focused teams. More specific scientific products should become work packages within a KSP

- Distinction between KSPs and Surveys: Each KSP may use multiple telescope surveys, each survey may be used by multiple KSPs

- Scientifically competitive, focusing on what can be accomplished with SKA1 in realistic time with commensality

- The system should encourage commensality both in surveys and in human-resources.

- Attract and assure people to invest significant time and resources to develop the tools for SKA KSP

Discussion Results

3 proposed KSPs from Cosmology SWG:

- 3D map of the Universe across cosmic time
- Testing the foundations of cosmology with radio continuum
- Direct mapping of dark matter with weak lensing

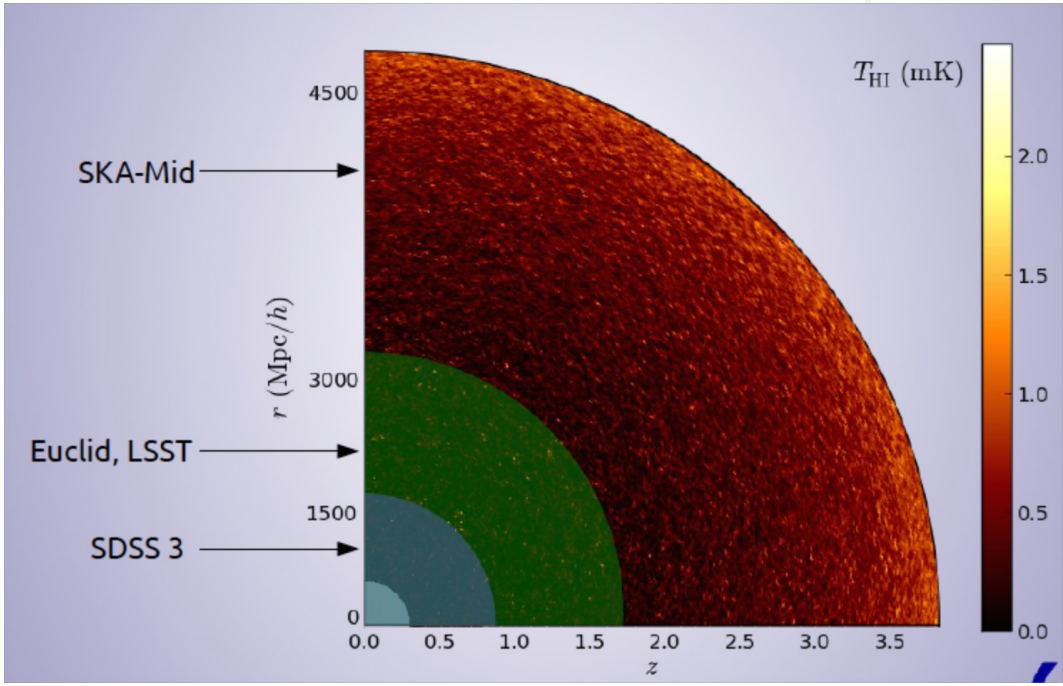
3D map of the Universe across cosmic time

- **Ultra-large scale Probe:**

Gigantic survey volume will enable game-changing measurement, best constraints of Non-Gaussianity, first detections of GR corrections, testing the cosmological principle

- **Precision Cosmology:**

BAO and H(z)/growth rate measurement, complements DETF stage-IV DE experiments such as Euclid

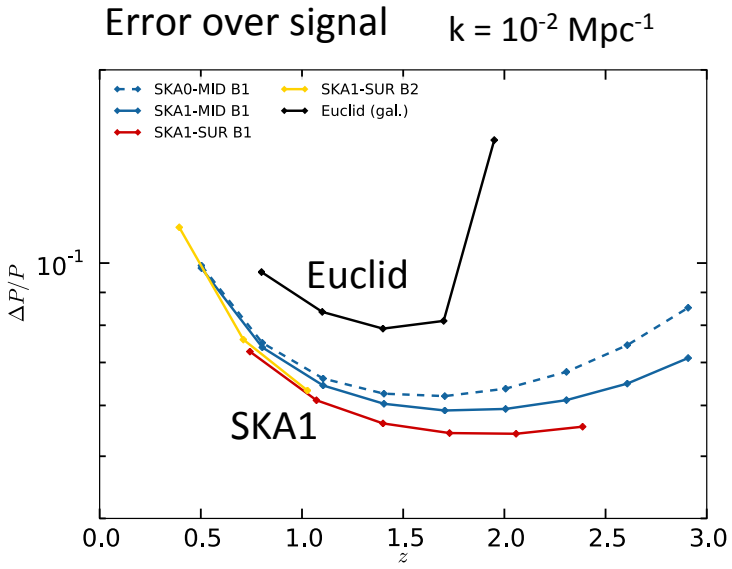


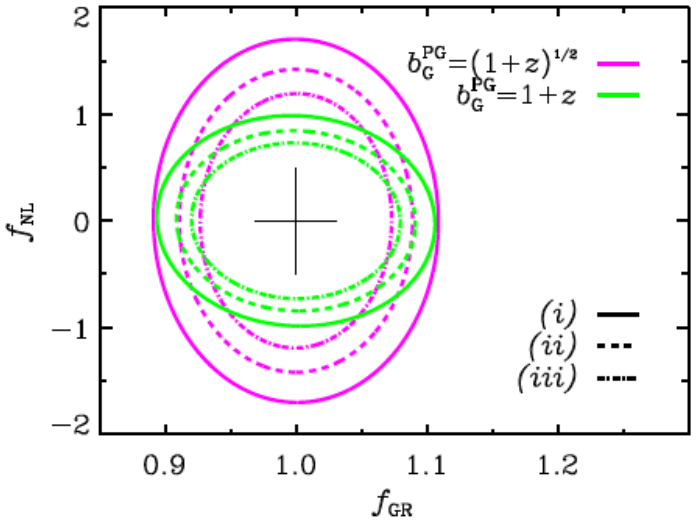
A Legacy Data Set: SKA has the unique capability to make the 3D HI map of the Universe from redshift 0 to 30 (z>6 for the EOR group)

BAOs and redshift-space distortions to be detected using wide/all-sky IM surveys over the entire $0 < z < 6$ range (and for the first time at $z > 3$), yielding precision constraints on modified gravity and dark energy

✓ Wide IM surveys out to z~2 will enable ultra-large scale cosmology – including novel tests of inflation and GR – through multi-tracer analyses. It can also be used for weak lensing.

✓A commensal wide HI galaxy survey will also measure BAO and growth at $z < 0.4$, as well as providing a large Tully-Fisher velocity catalogue and real-time cosmology pathfinder fields



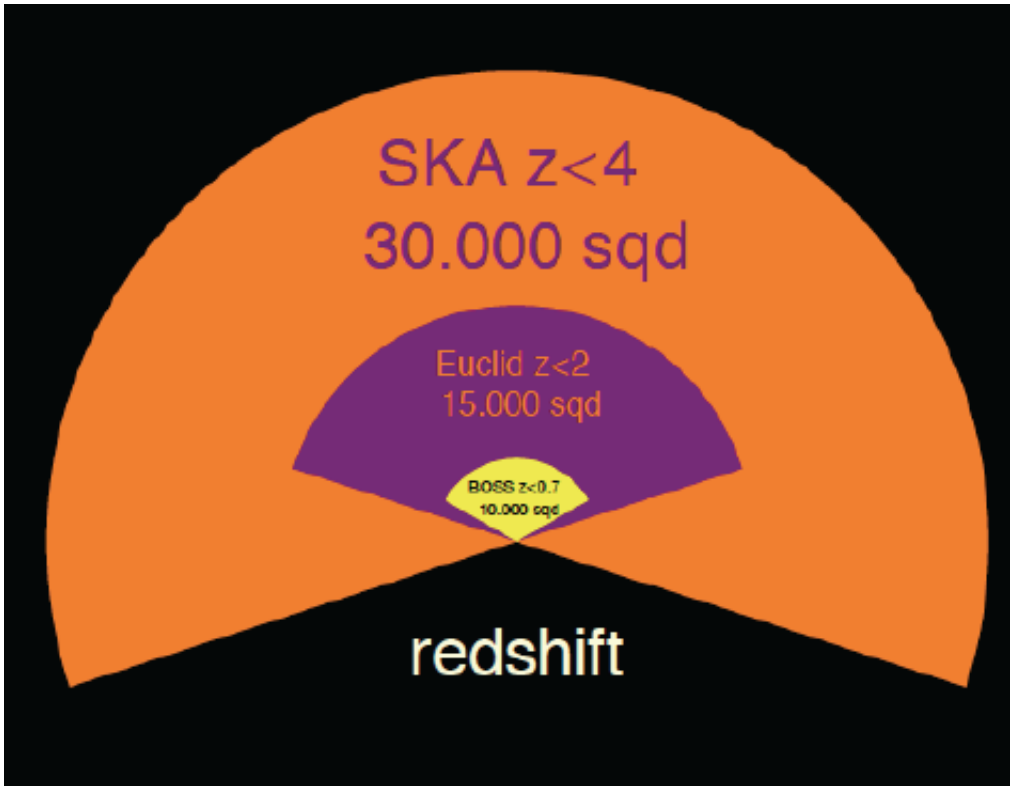


Fonseca et al.2015, Alonso et al. 2015

Testing the foundations of cosmology with radio continuum

- Radio continuum surveys provide unequalled probe of very high redshifts compared to optical surveys.

- Allows unique measurement of large scale effects on the galaxy power specytrum



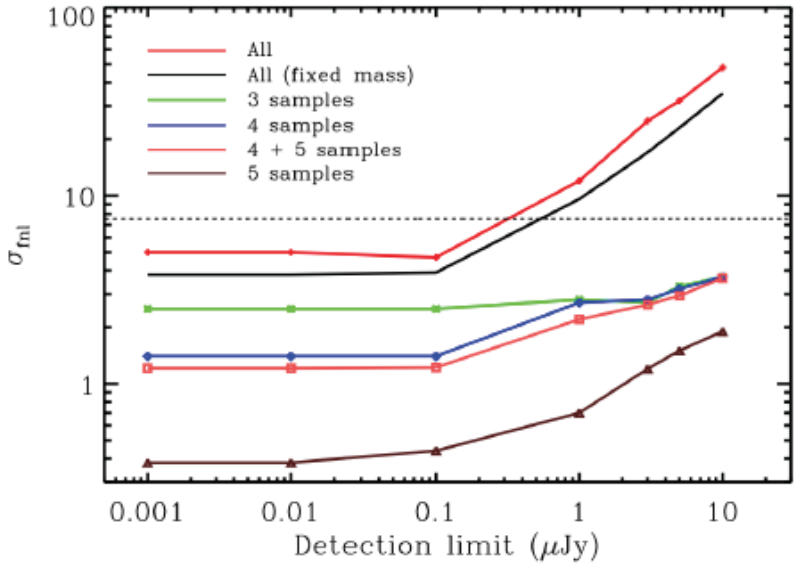
Jarvis et al. 2015

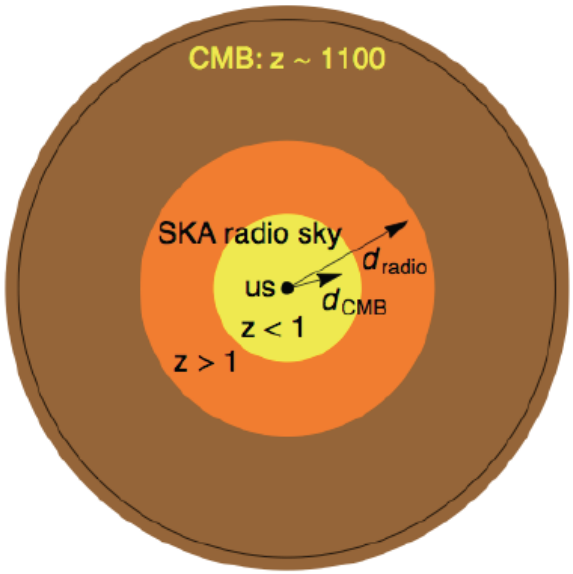
Ferramacho et al. (2014)

✓ **Angular power spectrum** measured in tomographic bins with multi-tracer technique, with the high-redshift tail providing measurement of the power spectrum on the largest scales leading to tests of primordial non-Gaussianity

✓ **Dipole measurement** measured precisely to test the cosmological principal of isotropy, when compared to the CMB

✓ **Cross-correlations with CMB lensing and optical surveys** to provide robust measurement of the radio source bias and investigate baryonic effects on the DM distribution on non-inear scales.



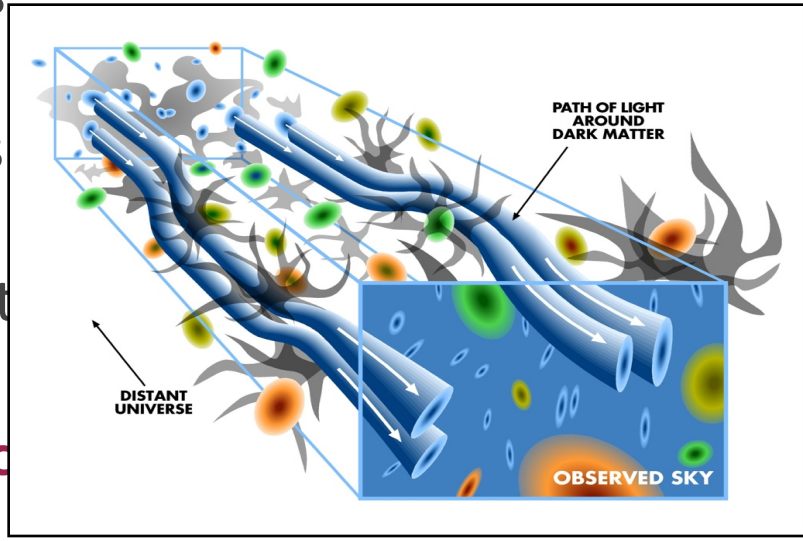


Direct mapping of dark matter with SKA1 weak lensing

- Weak Lensing (WL) is coherent distortion in shapes of distant galaxies due to light deflection caused by intervening **dark matter** distributions

- Measure WL as function of redshift t constrain growth of dark matter structure and hence **probe the physic of the accelerating Universe**.

- Traditionally done in optical but **SKA1 offers exciting new and unique ways to perform WL experiments**

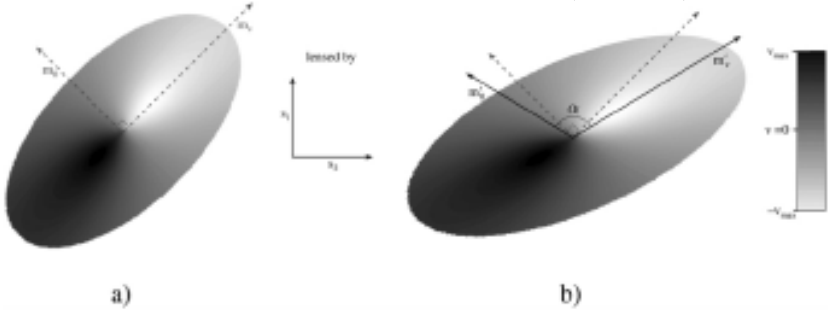


✓ **Extend reach of WL to high-z** to provide more powerful redshift lever-arm for constraining dark energy physics.

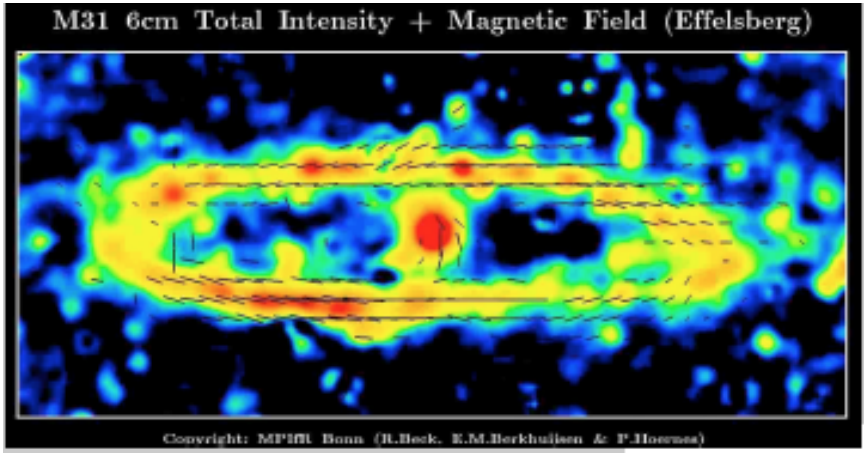
✓ Instrumental PSFs are severe problem in optical for measuring shapes. SKA will have **stable/ deterministic synthesised beams** ⇒ systematics less of a problem.

✓ Use **radio polarization to remove contamination from intrinsic galaxy alignments** - the key astrophysical systematic that limits WL at all wavelengths.

Morales (2006)



Berkhuijsen, Beck & Hoernes (2003)



HI Surveys

- High-z HI Intensity Mapping survey (z~2): B1 all−sky

Best constraints on non-Gaussianity, GR effect, probe ultra-large scale

Commensality: all sky continuum survey, HI absorption, magnetism, transients

- Low-z HI IM and Galaxy survey: B2 all−sky

Best constraints on Dark Energy/Modified Gravity, complements Euclid

Commensality: Cosmology continuum, Cosmology WL, magnetism, transients

- Post-Reionization HI IM survey： SKA-low 1000 deg^2

HI map at high z, first detection of BAO at z>3, massive neutrino

Commensality: HI absorption, EoR, transients

Special Requirements & Preference:

- IM use both single dish and interferometer data, require calibrated auto-correlation (ECP accepted)
- IM needs OTF scanning
- HI galaxy survey frequency resolution: 10kHz

Continuum and WL Surveys

- All sky continuum survey: B2 all−sky, centered at 1GHz

largest catalogue of galaxies ever, constrain dark energy/modified gravity, test isotropy, measure cosmological dipole, constrain non-Gaussianity, radio-optical cross-correlation and good SNR for linear-scale

Commensality: HI cosmology, continuum cosmology, magnetism, transients

- Weak Lensing Survey: B2 1000 deg^2

optimal for radio auto-correlation

Commensality: continuum(cosmology), continuum (SFR of the Universe), HI galaxies and HI cosmology (galaxy survey), transients

- Ultra-Deep Survey： B2 10 deg^2

calibration for WL

Commensality: continuum(cosmology), continuum (SFR of the Universe), transients

Special Requirements & Preference:

calibrated gridded visibility data.

Favour frequency centred at 1 GHz +- 200 MHz, overlap with optical WL survey field

Summary of Surveys Requested

	All sky (10,000hr)	1000 **deg^2** (10,000hr)	10 **deg^2** (1,000hr)
SKA-low		HI intensity mapping survey	
SKA-mid B1	HI IM		
SKA-mid B2	HI IM+Gal, Continuum+WL	Weak Lensing	Weak Lensing Calibration

Plans

- Inform the whole SWG, discuss the KSPs suggested here, moving toward KSP teams with resources/skills
- Forming a core team with members who are willing to actively participate, set up regular teleconfs
- Yearly Meeting for the SWG


Thanks!