Cosmic Dawn-Epoch of Reionization Science Assessment Workshop Summary

2013 April 10

Summary:

A science assessment workshop focused on the SKA1 Baseline Design and its ability to conduct science observations relevant to Cosmic Dawn and the Epoch of Reionization was hosted by the SKA Office on 2013 March 26–28. There was also discussion of the path toward SKA2. This document summarizes the main conclusions and where work is needed over the coming months by the SKA EoR Science Team, possibly leading to requests for changes to the Baseline Design before 2013 October.

Frequency Coverage: There was good agreement on the Baseline Design frequency coverage. Reducing the lowest operational frequency to 50 MHz was seen as a very positive development. The higher frequency limit of 300–350 MHz is sufficient to cover the end of the EoR and might even enable some intensity mapping after the EoR. The current design was also recognised as sufficient for high *z* H I absorption studies. *No major changes are likely be recommended, but the Science Team will investigate whether the dense-sparse "transition" frequency should be shifted somewhat below 100 MHz in order to optimize for sensitivity at high z. The Team recognises the potential impact for the sensitivity of the SKA1 at higher frequencies and that such a change might require an increase in physical collecting area in order to compensate for the loss in A_{eff}/T_{sys} above the "transition" frequency. The Team will also assess whether a small frequency buffer below 50 MHz should be recommended. No recommendations for change will be made at this time.*

Required A/T, sensitivity: A brightness temperature sensitivity limit of 1 mK in 1000 hrs on 1‘ scales is broadly agreed upon as stated in the baseline design and DRM, but it was recognized that this would only be achieved in an rms sense in power-spectra measurements during the EoR, not during the CD. Tomography can be done on scales ~5‘ at 200 MHz, increasing to scales ~1º at 50 MHz inside neutral patches. It was recognised that this is unavoidable without increasing the collecting area of SKA by 1–2 orders of magnitude. However, it was also noted that 1‘ tomography can be done during the EoR to map out ionized bubbles that have a contrast of 20–30 mK with respect to neutral patches. *Overall the current Baseline Design was agreed as being close to optimal within given boundaries. No major changes are likely to be recommended, but the Science Team will look in to minor adjustments of the core size, to gain a little in angular resolution without impacting the brightness temperature sensitivity too much due to sparsening of the array. No recommendations for change will be made at this time.*

Station-size/FoV/Multi-beaming: Interesting angular scales during the CD-EoR range from arcminute to ~1º. Whereas there was agreement that one should image these scales, there was some disagreement on whether this can be done though mosaicing the images produced from smaller beams/beamlets (i.e., from larger stations) or whether it is better to produce these images using a single beam (i.e., from a smaller station). The disagreement centered less on whether mosaicing can be done in principle, but more around whether the resulting images would be reliable, especially since the CD-EoR H I intensity levels would be at a level of ~10^{-4} from foregrounds that show structure on similar scales. The argument in favour of larger stations would be, in part, a reduced computational burden (correlation and imaging) and possibly improved calibratability. *Overall this was recognised that the current station-size/field-of-view of > 4º is sufficient to reach all stated science goals, but the Science Team will study the feasibility of mosaiced multi-beam images versus large single beam images of similar field-of-view and the*

impact of mosaicking on sensitivity for tomography and power-spectra. It will also look into the hierarchy of beamforming/correlation inter- versus intra-station. A CD-EoR Science memo should be written on this topic.

Station distribution/*u-v* coverage: The current Baseline Design (core) will be able to reach the 1 mK power spectrum limit within ~1000 hrs, and there were no major concerns identified. The core size seems matched well with tomography, i.e., ~5' resolution at 200 MHz, which would allow imaging to the 1 mK level. The FWHM angular scale increases roughly to match the tomography requirement. *The Science Team will look into the impact on the CD-EoR science case of having baseline redundancy in the core, although the high filling factor will almost guarantee this. In addition, it will look into a slight expansion of the core. No recommendations for change will be made at this time.*

Long Baselines: Arguments were made in favour of having longer baselines: calibration, information content, ionosphere, reducing confusion noise, but what maximum baseline length is required remains open, and was recognised as a very important issue that needs to be addressed quickly. Longer baselines, it was argued, could be essential to keep the interest of a wider (non-EoR) community, since the telescope can only do EoR science a fraction of the year. Having confusion noise-limited short-baseline images will be of less interest to the wider community. *The Science Team will assess what the minimum maximum-baseline length should be for CD-EoR science and how many stations are needed at longer (outside core) baselines. A CD-EoR science-team memo should be written on this topic.*

Log-Periodic Elements: It was recognised that the drop-off in sensitivity with zenith angle (which scales as cos θ) is acceptable for CD-EoR science given that one wants to observe around the zenith and has a limited observing window, due to a desire to avoid observing close to the Galactic plane. Questions were raised regarding the beam pattern and whether this receptor behaves well over the desired wide frequency range especially if the optimal frequency is in the lower part of the frequency range. It was recognised that using circular polarisation feeds will not help. *The Science Team will look into the impact of the frequency dependent beam pattern on the ability to do tomography over the full frequency range (w/varying resolution) and look into polarization purity and the ability to measure Faraday rotation. No recommendations for change will be made at this time.*

Computational Costs and Data Products: It is recognised that the computational costs of a CD-EoR experiment can be high and that long-baselines and station size play a prominent role here. Overall the EoR community would like to work with some level of preprocessed visibilities. *At the moment the Science Team makes no recommendations, but it will try to scale LOFAR/MWA/PAPER/GMRT computing costs to SKA1.*

Path to SKA2: Overall it was recognised that SKA_Low should also excite a wider community and that the inclusion of longer baselines would be a requirement for doing so. Important (future) upgrades from the current baseline design could be multi-beaming and an increased A/T at either very low frequencies (< 100 MHz) and/or higher frequencies (> 200 MHz) for CD and/or intensity mapping studies, respectively. Finally, baselines longer than the currently recommended 100 km could be added to attract a wider science community. More general discussions focussed on that any major design change should focus on science goals where SKA (1 & 2) can be unique, and maybe also on exciting the physics community. A deeper thinking on complementarity with other instruments/surveys should also be encouraged in this process.

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