

# The Square Kilometer Array

## The Path to Level 0 Science

v2.0, 2003 August 5

### 1 INTRODUCTION

Radio astronomy has a long history of developing innovative instrumentation and of making ground-breaking astronomical discoveries. Using this heritage as a foundation, an international consortium of scientists and engineers is planning the Square Kilometer Array (SKA),<sup>1</sup> a next-generation radio telescope to be constructed 10–15 years hence. Several designs and sites have been proposed for the SKA,<sup>2</sup> all of which are currently being evaluated and iterated on by various consortia, coordinated under the International SKA Steering Committee (ISSC).

The SKA represents a great leap forward over the capabilities of current radio telescopes. Thus the list of proposed SKA science projects is very long.<sup>3</sup> Many of these projects have conflicting requirements in terms of frequency coverage, array configuration and siting. Some of these projects have considerable synergy with future initiatives in other wavebands, while others are unique to radio astronomy. There is a need to prioritise and classify all the various science goals, so as to establish which science goals should constrain design and siting decisions, and also to identify which scientific goals should be used to “sell” SKA to the astronomical community, to funding agencies, and to the public.

The ISSC has correspondingly appointed an International Science Advisory Committee (ISAC),<sup>4</sup> who have been charged with identifying, developing and prioritising the science goals for the SKA. The ISAC has formed nine working groups representing a broad range of science topics. Within each working group, various proposed science projects have been classified as:

- “Level 1” — unique and important SKA science
- “Level 2” — important science, but not uniquely addressable by the SKA
- “Level 3” — other interesting projects, which may well make up the “bread and butter” of SKA observations, but which are not anticipated to have far-reaching consequences for our understanding

This process has culminated in the “ISAC Matrix”, which identifies 18 level-1 science projects, and for each such project rates the capability of the seven currently proposed SKA designs.<sup>5</sup>

### 2 LEVEL 0 SCIENCE

While the work carried out by the ISAC to date has proven very useful, there is a strong feeling that the SKA community needs to identify a handful of “level 0” science goals, which will be used to attract funding and publicity, which will be the focus of efforts to ensure that SKA work complements work which will be done by other future telescopes, and which will be those projects for which the SKA design will be specifically optimised.

Accordingly, the ISAC has formed a “Level Zero Subcommittee” (LZSC), whose charge is to:

<sup>1</sup>See <http://www.skatelescope.org>.

<sup>2</sup>Individual white papers are available at [http://www.skatelescope.org/ska\\_documents.shtml](http://www.skatelescope.org/ska_documents.shtml).

<sup>3</sup>See [http://www.skatelescope.org/ska\\_science.shtml](http://www.skatelescope.org/ska_science.shtml).

<sup>4</sup>A current list of ISAC members is available at <http://www.skatelescope.org/ISAC.shtml>.

<sup>5</sup>The current matrix is listed at [http://www-astro.physics.ox.ac.uk/~sr/ska/ska\\_matrix.html](http://www-astro.physics.ox.ac.uk/~sr/ska/ska_matrix.html).

- Propose a set of definitions for “level 0” science.
- Suggest a preliminary list of level 0 topics.
- Identify a process through which the ISAC can converge on a specific set of level-0 science topics, and coordinate the corresponding process through which level-0 topics are proposed, reviewed and refined.

The LZSC was convened in May 2003 and currently consists of ISAC members Bryan Gaensler (chair), Frank Briggs, Sean Dougherty and Steve Rawlings. Below we summarise the progress of the LZSC on the above issues.

## 2.1 Definitions for Level-0 Science

A variety of definitions have been proposed for level-0 science. These include “uniquely addressable by SKA”, “drive design of telescope”, “use to sell to funding agencies”, “up front on WWW page / talks”, “lose large section of radio community if disallowed by design”, and “most interesting to wider (non-radio) astrophysics community”. The LZSC has considered these and other definitions, and has also looked at what constitutes the equivalent of level-0 science for other future telescopes such as *JWST*, ALMA and *Constellation-X*. We propose the following definitions for level-0 SKA science, for consideration by the ISAC:

1. Can address important but currently unanswered questions in fundamental physics or astrophysics.
2. Is science which is either unique to the radio band and to the SKA, or is something which is complementary to other data-sets but in which the SKA plays a key role.
3. Excites the broader community, and is of relevance and interest to funding agencies.

Regarding criterion (1), the LZSC recommends that of the final list of level-0 topics, at least some should address outstanding issues in fundamental physics,<sup>6</sup> while others should be focused on more traditional astronomical questions.<sup>7</sup> Ideally, level-0 topics should offer “transformational” advances, rather than just incremental steps such as better statistics or smaller error bars.

Careful consideration needs to be made regarding criterion (2). On the one hand, science which is completely unique to the SKA is particularly appealing to the radio community, but might not be of interest to researchers working in other wavebands. On the other hand, there are many profoundly important topics to which SKA might contribute, but for which another telescope might already have addressed the outstanding issues by the time the SKA begins observations. There must therefore be a trade-off between science which is uniquely addressable with the SKA, and that which represents the outstanding questions in astronomy, and which many telescopes might be able to address.

Regarding criterion (3), the SKA consortium needs to ensure that the level-0 projects align with the broad themes and priority areas laid out by various funding agencies (for example, NASA emphasises topics such as “origins”, “structure” and “evolution”). The demand for topics which are of interest to the broader community entails that we should not just be looking to promote some

<sup>6</sup>As outlined, for example, in “Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century” (US National Research Council, 2003).

<sup>7</sup>A useful summary of such issues is the McKee & Taylor US Decadal Review, “Astronomy and Astrophysics in the New Millennium” (US National Research Council, 2001).

subset of the existing 18 level-1 topics, but rather should be looking for themes which encompass many topics or experiments.

We note that the above definitions potentially exclude: topics which are currently interesting but will be addressed by other experiments (e.g. LOFAR or ALMA); topics which are of ongoing interest to radio astronomers but don't have broad appeal to the astronomical community; measurements which can be done now or in the near future, but for which we can find fainter objects or accumulate more statistics with an SKA.

One issue of much discussion has been that of serendipity. Just has been the case with earlier radio telescope, there is certainly no doubt that the SKA will make many serendipitous discoveries, and indeed such discoveries may be the SKA's defining contribution to science. However, the topic of "serendipity" does not meet the definitions outlined above. The recommendation of the LZSC is therefore that serendipitous discoveries and the expansion of phase space not be included as level-0 science, but that serendipity be explicitly included in the science case as an additional motivation for building the SKA.

## 2.2 Process for Identifying Level-0 SKA Science

The LZSC proposes that the final list of level-0 science should contain 3–5 projects. Less than this will result on over-reliance on particular predictions or extrapolations and might lack broad appeal; too many projects will send a confusing message to the wider community.

A brief roadmap of how this process might proceed is as follows:

- Aug 2003: A call for proposals will be issued to the ISAC and Scientific Working Groups, and through them to the various science working groups and wider community. A response to this call should take the form of a brief (one page or less) submission, outlining a particular topic and explaining how it meets the criteria outlined in §2.1 above.
- 1 Oct 2003: Proposals for level-0 science due to LZSC.
- Oct 2003: Short response from level-0 subcommittee, followed by a brief opportunity for mergers and iteration.
- Nov 2003: Vote, ranking and culling of proposals by the ISAC (the initial results of this process will be announced at the Leiden science retreat).
- early 2004: Review of topics and rankings by external panel; simulations carried out by the SKA Simulation Working Group.
- mid 2004: "Level 0" chapters for science book; Berlin SKA/ALMA/JWST/ELT meeting.
- mid 2004: Shortlist and recommendations submitted to ISSC for final decision on 3–5 level-0 projects.
- 2004+: Topics and science case on WWW site, in outreach materials and in proposals.

Throughout the process of converging on a list of level-0 topics, two important points need to be kept in mind. First, we acknowledge that many important SKA discoveries will come from unexpected areas, not covered by the final list of level-0 (or even level-1) topics. In finalising the list of level-0 goals, it is thus important to bear in mind that even if these projects drive and constrain the design, the telescope should still be kept sufficiently flexible so as to be capable of many other experiments. Second, while the final list of level-0 topics will not necessarily encompass

all level-1 science, the corresponding instrumental specifications should ideally not prevent most level-1 science topics from still being carried out. Overall, the LZSC encourages the community to identify those science topics which are most compelling, rather than to be concerned about one's own favourite project missing out on being designated as level-0 science.

### 2.3 Examples of Level-0 Topics

As a starting point for further discussions, the ISAC has identified a variety of potential topics which might meet the criteria for level-0 science outlined in §2.1 above. These topics (in no particular order) are:

- The origin of cosmic magnetic fields
- Probing gravity through pulsars
- The Dark Ages and Epoch of Reionisation
- Large scale structure and Dark Energy
- Formation of supermassive black holes
- Cosmic accelerators
- Galaxy formation and evolution
- The transient Universe
- The search for extraterrestrial intelligence
- The origin and evolution of the intergalactic medium
- Protoplanetary disks