The Unknown Unknowns

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The starting point

….as the design and operating concepts for the SKA1 system begin to solidify…..

…..as new scientists and engineers join the project

….as the pressures come on to maintain costs within a given envelope

➔ update the rationale for “Exploration of the Unknown” (EoU) - transients likely to play a major role…..
“The SKA will address many currently topical problems in astronomy and astrophysics. But, these are today’s problems—will they still be the outstanding problems that will challenge astronomers in the period 2025 to 2050 and beyond, when the SKA will be in its most productive years?

“If history is any guide, the excitement of the SKA will not be in the old questions which are answered, but the new questions which will be raised by the new types of observations it (alone) will permit.”

“Discovery is important in astronomy because we are not sufficiently imaginative to construct the Universe and its constituents from first principles...”. Kulkarni (2012)
Initial SKA community response.

......the topic of “serendipity” does not meet the [level 0] definitions... 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

Followed though to a significant extent - but not enough?

Flexibility of design and operation deserves to be an explicitly recognised section in the SKA1 design - which will feed though to SKA2
Lessons of history - 1

Discovery can be planned generically...

- explore new regions of parameter space: enabled by technical innovation (Harwit)

In the deca- to centimetre waveband

i) Telescopes with large collecting areas of dominate the list of discoveries......
Lessons of history - 2

In the deca- to centimetre waveband

ii) Rate of discovery has slowed in past decade

<table>
<thead>
<tr>
<th>Decade</th>
<th>Number of discoveries</th>
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<tbody>
<tr>
<td>1930-9</td>
<td>1</td>
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<tr>
<td>1940-9</td>
<td>2</td>
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<td>1960-9</td>
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<td>1970-9</td>
<td>6</td>
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</tr>
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<td>1990-9</td>
<td>8</td>
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<tr>
<td>2000-9</td>
<td>4</td>
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LOFAR building
JVLA/eMERLIN - upgrading
Lessons of history - 3

In the deca- to centimetre waveband

iii) Telescope designers did not anticipate what they would be known for... (also HST! - Norris talk)

iv) Discoverers generally had access to lots of telescope time....

v) In the majority of cases discoveries were not theory-driven
Conclusion so far...

The SKA’s place in astronomical history will not all be found within the pages of the science case!

So what do we do about it?

Liberate SKA’s discovery potential...
new things will be weak and/or rare and/or involve an unexplored region of parameter space
Planning discovery - technical

Harwit’s phase space: large jumps in at least one of:
- sensitivity;
- spatial coverage and/or resolution;
- temporal coverage and/or resolution;
- spectral coverage and/or resolution;

Can now add:
- availability of past observations (e.g. discovery of FRBs)

SKA1 offers “transformational” performance ⇒ expect to find unexpected phenomena– but only if “the system” allows users the maximum chance to do so.
EoU principles are recognised.

“.....designed in a manner to affordably allow flexibility and evolution of its capabilities to probe new parameter space (e.g. *time variable phenomena*.....)”

• to provide the capability to carry out small-scale, experimental observations that utilise the outputs of tied-array beams from one or more sub-arrays....

• ...capable of rapid reconfiguration of their observing mode in response to internal or externally generated, pre-defined triggers.....

• ...enable commensal observations.....
Is technology the only answer?

No! - there is also the human factor

“In the field of observation chance favours the prepared mind”

-Louis Pasteur

The most exciting phrase to hear in science, the one that heralds new discovery, is not “Eureka” but “That’s funny…”

-Isaac Asimov
People make the discoveries

Discoveries are made by clever people getting large amounts of “telescope time” and hence able to recognise the unusual.

→ system flexibility and the concomitant “brain multiplexing factor” (human bandwidth) is an additional phase space axis
Human bandwidth

A new phase space axis:

i.e. scope for many as many people as possible to gain access to SKA data and for expression of their curiosity in its use.
Seek constructive ways of establishing parallel access to the data – current thinking with:

“Citizen Science”: a proven route e.g. recent successes of Einstein@home in finding new pulsars

The SKA was born global – so let it be a globally accessible source of archived data (even allowing for a delay).

Archival papers form an increasing fraction from major facilities.

FRIDAY session 17
Synergies with other telescopes

An aspect of human bandwidth...

For first time an object detected in any EM waveband may be detected in the radio - certainly with SKA2 (see also Norris talk)

The opportunities for data linkages with ground and space-based telescopes are enormously greater than with any previous radio telescope.

SKA should commit resource to international Virtual Observatories - maximising access to multi-wavelength data.

FRIDAY session 17
Observational Space

J. Cordes and the International SKA SWG (Memo 85):

i) New objects in known classes → **SKA science case**:

ii) Targeted known phenomena: → **SKA science case**

iii) New Classes/Phenomena based on known science. e.g.

- transient sources of many kinds
- new cosmological structures
- etc

iv) The totally unexpected:

look in new areas of parameter space
“One might think that all of the key variables have been probed with existing telescopes. This is far from being the case because the so-defined parameter space has been investigated only in very compartmentalized sub-volumes.”

J. Cordes and the International SKA SWG (Memo 85):
A Phenomenological Approach

Zwicky’s “morphological” methodology can complement existing thinking ... All volume elements in parameter space - not explicitly prohibited - may offer innovative ways forward.

Simple matrix as a start - will be filled in for the paper.

<table>
<thead>
<tr>
<th>OBSERVING TIME</th>
<th>TOTAL INTENSITY</th>
<th>POLARISED INTENSITY</th>
<th>SPECTRAL PATTERN</th>
<th>SPECTRAL RESOLUTION</th>
<th>SPATIAL PATTERN</th>
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<td>Low</td>
<td>high SNR</td>
<td>low</td>
<td>long term</td>
<td>High</td>
</tr>
</tbody>
</table>

2 KSPs
The “EoU vision”- bottom line

- SKA1 design process should explicitly address the wide range of flexibility options to maximise human bandwidth & advance a holistic EoU vision from the most cost-effective.

- Pay the price: <10% collecting area for a given overall budget
  → in some cases <20% longer to complete a given project (if noise limited)
  → but many more projects & minds involved
  → likely to be a good bargain
The unknown unknowns

the known knowns

read the literature

write a proposal

hold to a vision

and remember....

discoveries with SKA1 will propel us to SKA2!
END