ASKAP in Perspective

ATNF Futures 2030 Workshop

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Marsfield
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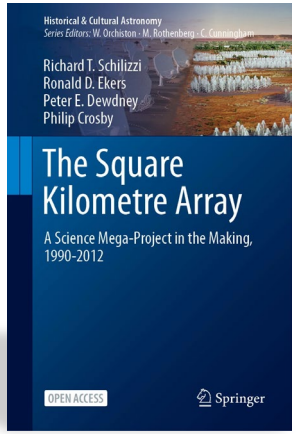
Sources

The Square Kilometre Array: A mega-science project in the making, 1990-2012

- Schilizzi, Ekers, Dewdney and Crosby
- Springer
- https://link.springer.com/book/10.1007/978-3-031-51374-9

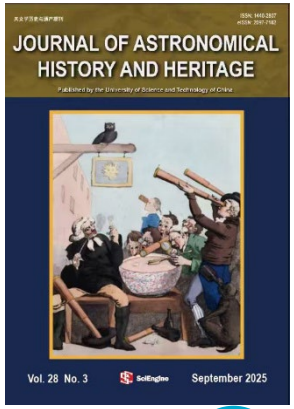


THE BIRTH OF ASKAP: A PERSONAL VIEW

– John Bunton

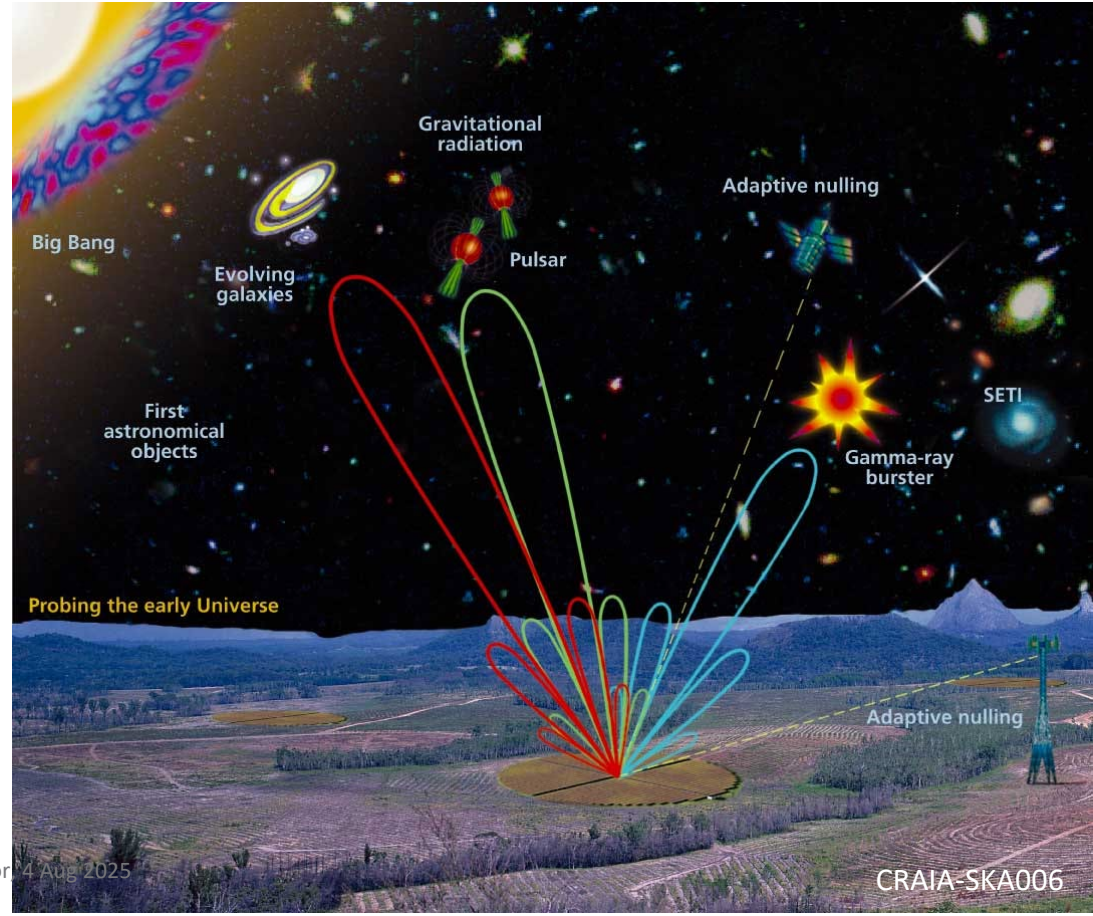
➢ JAHH volume 28 issue 3 p568.

➢ https://www.sciengine.com/JAHH/doi/10.3724/SP.J.1440-2807.2025.03.02



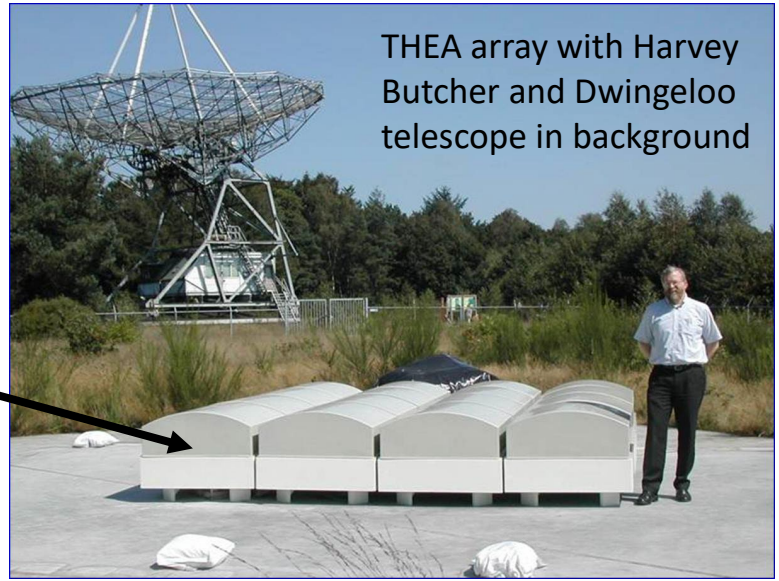
SKA all sky multibeam concept - 1998

- Analogous to the multiple high energy projects sharing particle accelerator beams
- Aperture re-use
- An innovative new technology development
- Radio Transient Working Group suggested at least 10 simultaneous beams
- Wide FoV requires aperture arrays

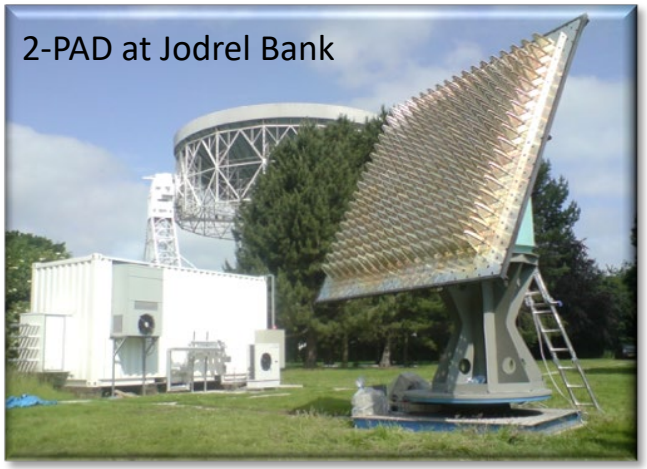


SKA Aperture Array concepts

- Thousand Element Array (THEA)
  - Astron 1999-2005
  - 16x 64 element tiles
  - 600-1700 MHz
  - Vivaldi elements



- SKADS – 2005-2010
  - EMBRACE
  - 2-PAD
  - BEST



What happened to the aperture arrays?

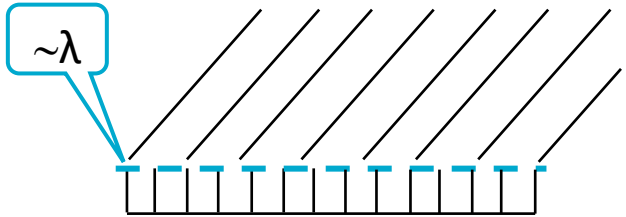
- 2003 to 2005 aperture array considerations
  - See John Bunton who was deeply involved in SKA engineering in this period
  - Cost of the huge number ~ A/λ^2 of active elements grows too fast with frequency to be economical.
  - The backend cost and data processing complexity meant that only a small subset of tied array beams where possible losing the FoV advantage
  - 1D and 2D focal plane array concepts emerged as a compromise
    - the dish or cylinder was a concentrator trading FoV for complexity
    - Canada implemented the SKA cylinder design as CHIME

- 2010 SKA technology down select
  - practical implementation of aperture arrays at short wavelengths for radio astronomy has yet to be achieved
  - Dense aperture arrays were moved to the SKA Advanced Instrumentation Program (AIP).

- It is now 15 years later, so are we ready yet?
  - Keith and Nithya will inform us
  - But the first step must be a modest demonstration

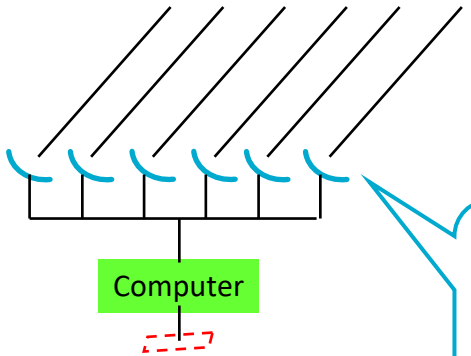
Radio Telescope Imaging – the case for a concentrator

Aperture array



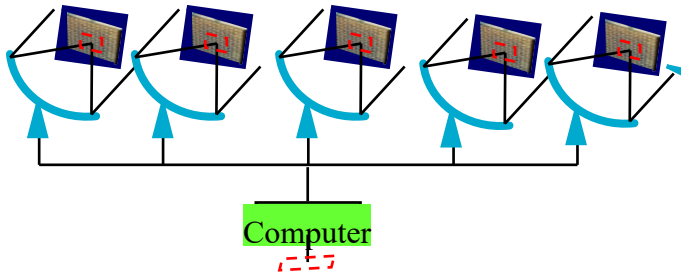
Active elements
~ A/λ^2

Dish array



Dishes act as concentrators
Reduced FoV but
greatly reduces number of active elements ~ A/d^2

Dish and focal plane array
For ASKAP x36 less correlators



Increase FoV in each dish,
multiple simultaneous aperture synthesis arrays in parallel

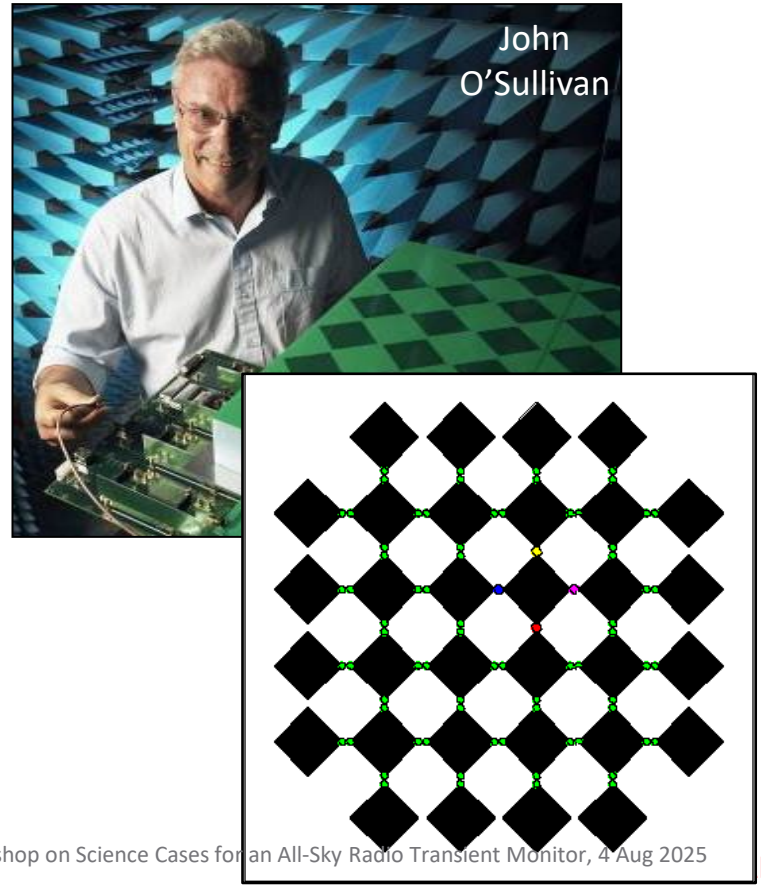
The path to ASKAP – an SKA pathfinder

- SKAs high political profile
  - OECD -> PMSEIC -> Foreign Affairs -> John Howard (then prime minister)
    - Australia as a significant player in a Global collaboration
  - Major recommendation in the Decadal review (2006-2015)
  - Governance: Australian SKA consortium - CSIRO, AAO, Universities, DST and later ICRA
- Initial funding
  - 2006 NCRIS $AUD 19M – via Jim Peacock (Chief Scientist)
  - 2006 CSIRO $AUD30M
  - 2007 DEST $AUD52M

What was ASKAP built for?

- The ASKAP telescope was built to:
  1. Establish an observatory site for the proposed SKA (with MWA)
     - This preceded any SKA-low site decision
  2. Demonstrate PAF-dish array technology for survey science
  3. Astronomically significant fallback if SKA or SKA site bid failed
     - The 10 antenna engineering proposal was increased to 30 (36) antennas
     - ASKAP is now the most complex telescope in operation today!
- Science Survey Projects
  - Following the construction of ASKAP, CSIRO ran an open proposal process, and initiated the 5-year Science Survey Projects, which are still in progress.

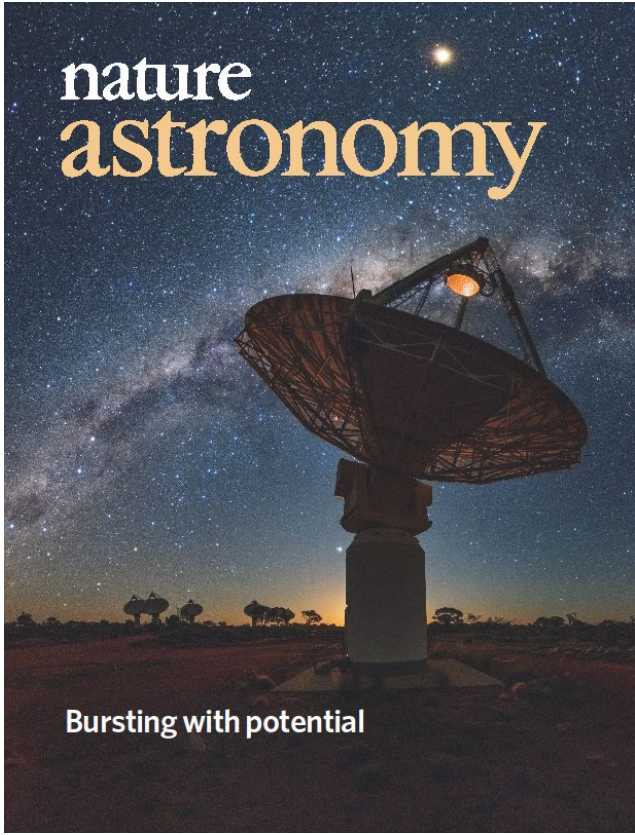
Checker Board Array – accept mutual coupling



- Self-complementary antenna
- Frequency independent free space impedance
  - 380 ohms
- Babinets Principal
- Differential amplifiers at vertices
- Accurate modelling possible

ASKAP and the impact of a large FoV

- The survey speed metric used for continuously emitting sources is inappropriate for transients.
  - See Josh Pritchard's talk or J-P Macquart paper
- The discovery space for new high s/n transient is linear with FoV hence ASKAPs high success with LPTs and FRBs
- Large FoV for space weather – John Morgan's talk
- Large FoV for rare objects – can be game changers
- Trading FoV for more sensitive short observations degrades UV coverage and limits accessible time scales
- Multiple simultaneous beams enables high risk projects.
- At radio wavelengths we can divide the photon stream with no loss in s/n.
  - eg FRB triggered voltage dumps



Accessing the transient phase space

- Short time scale
  - low angular resolution single dish
  - Time differencing removes confusion and gain changes
- Slow transients
  - High angular resolution arrays
  - Can remove slowly changing confusion, red noise and rfi
- LPTs, IPS
  - large FoV arrays that can operate on short time scales
  - ASKAP and MWA have filled this gap and made discoveries
  - But specialised instruments may be better

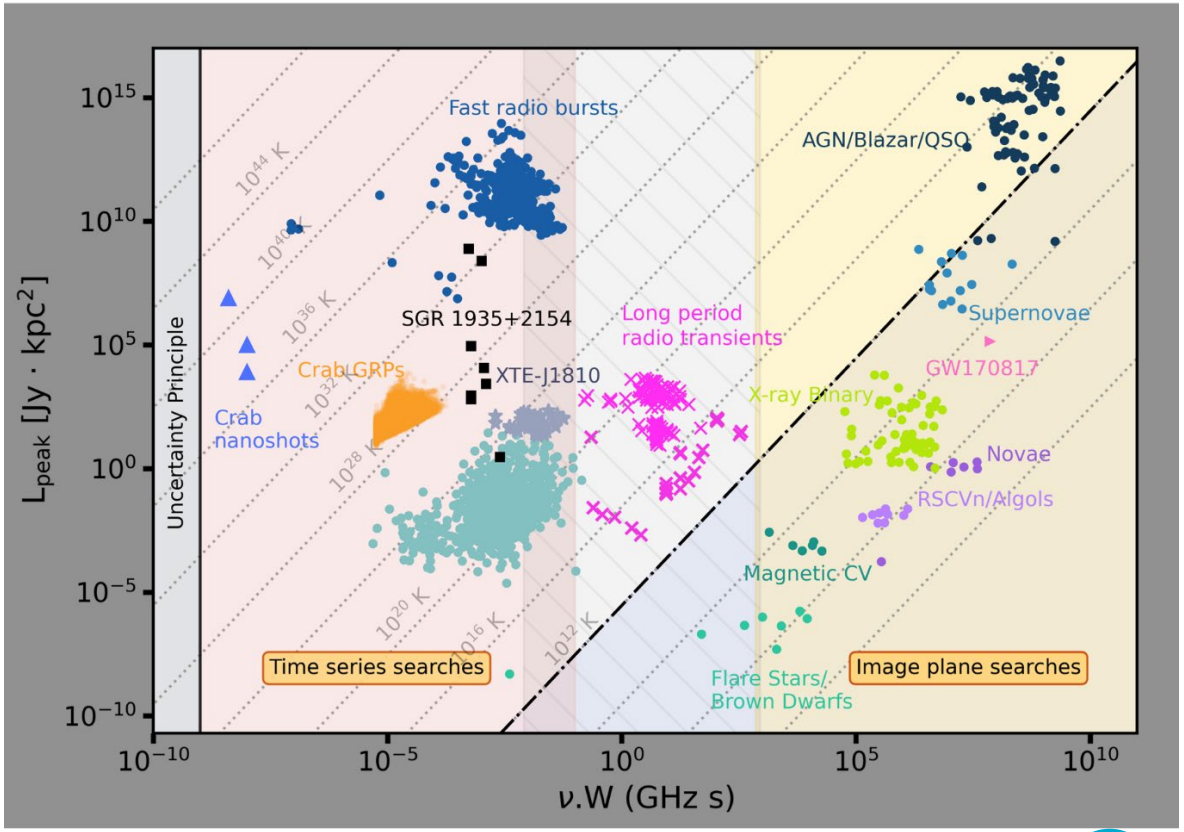
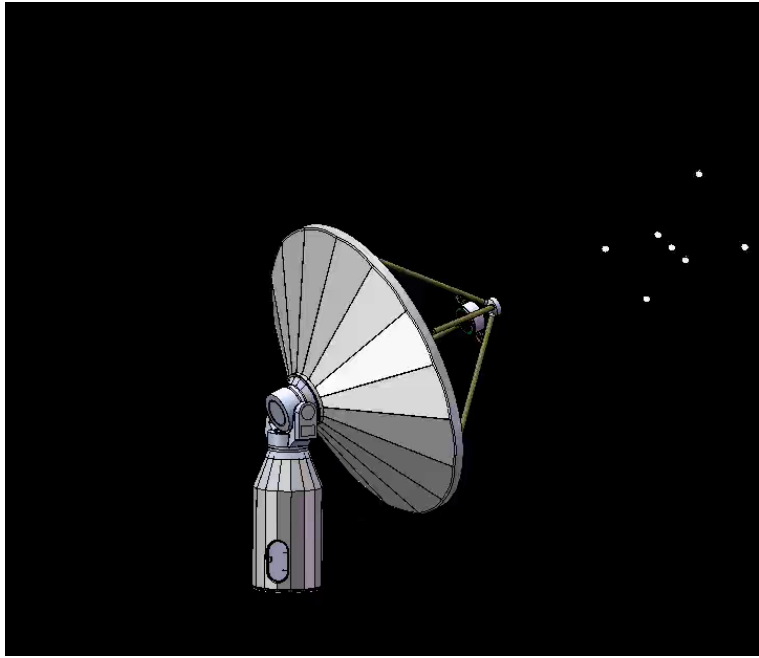
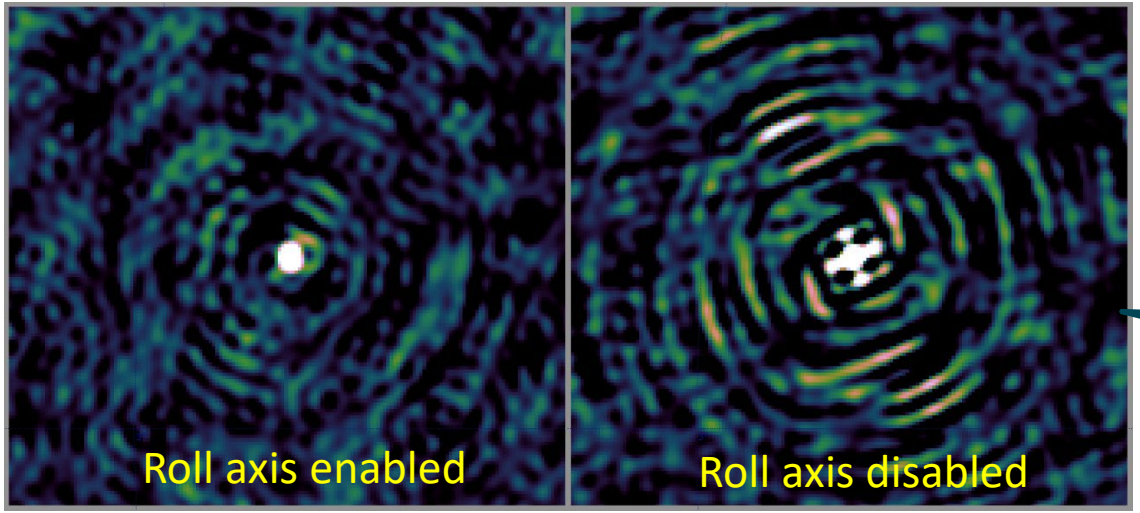


Image credit - Kovi Rose

Three axis symmetrical mount

- Introduced to simplify use of a focal plane array
  - But so much more!
- 10% incremental cost for 3 axis mount
- Ian Heywood tests – source 2.75d off axis
- Essential for wide field polarization
- SKA-mid cannot do this





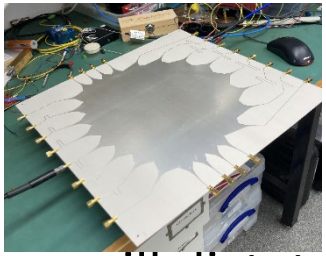
The power of a simple analogue solution

My Vision for our Future

- We already have one of the most successful radio telescopes in the world - ASKAP
  - So why not upgrade it
  - It may be too big for one country – find partners
  - Similar survey speed as SKA mid for a fraction of the cost.
- Build a prototype aperture array – they may be the future, but we have to learn how to do it first.
  - 100 element (2m) aperture array
  - 3 stations separated by about 10km
  - good and unique science case (CASPA proposal).
  - All sky all the time
  - This is a 3Sx100eps array in Keith's notation. Cost < $10M.

My longer term Vision

- We will need to constrained energy requirements
- Move back to analogue computing
  - Quantum computing
  - Rotman Lens (low power, wide bandwidth)
  - Optical processors



- Our changing understanding of the Universe will dictate future science
  - Not current fashions
  - Dark matter
    - DM particle detection – array of autocorrelation detectors (ASKAP has 1296!)
  - Dark energy
  - The reconciliation between quantum mechanics and Gravity
  - We have almost no understanding of the beginning of the Universe
    - Direct detection of EoR – 1km square connected phased array (not SKA-low)
    - (Re)-combination lines at z=1000