MANCHESTER 1824

SKA Group

Richard Schilizzi

JBCA Symposium, 31 October 2012

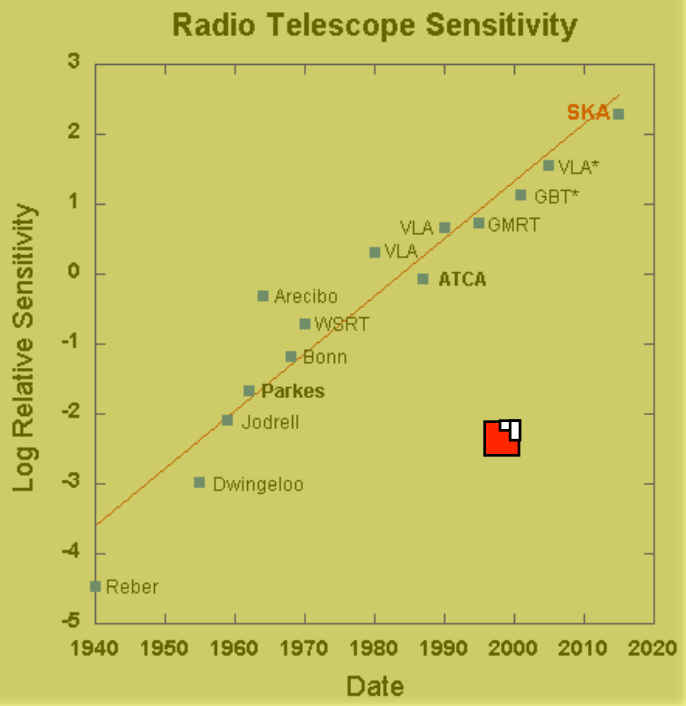
The SKA

a large radio telescope for transformational science

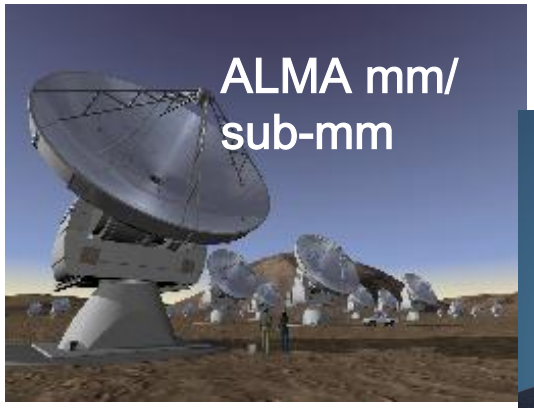
- up to 1 million m^2 collecting area distributed over a distance of 3000+ km

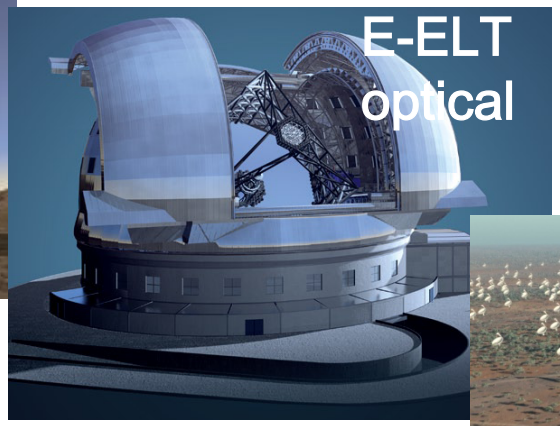
- operating as a wide-field interferometer at frequencies from 70 MHz to10 GHz (4m-3cm) with two or more detector technologies

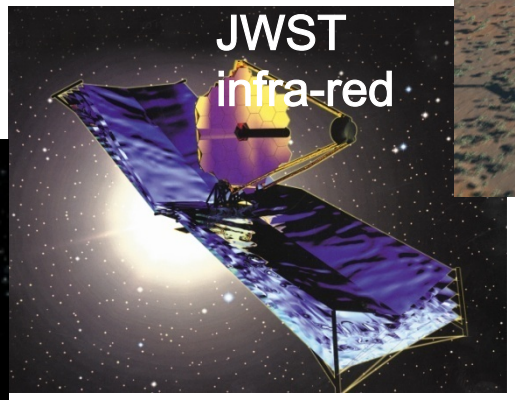
- connected to a signal processor and high performance computing system by an optical fibre network (sensor network)



The Great Observatories for the coming decades







SKA Key Science Drivers

ORIGINS

- The history of the Universe in neutral hydrogen

  Probing the dark ages: When did the first stars and galaxies form?
  How did galaxies evolve?
  Dark Energy, Dark Matter

- Astro-biology

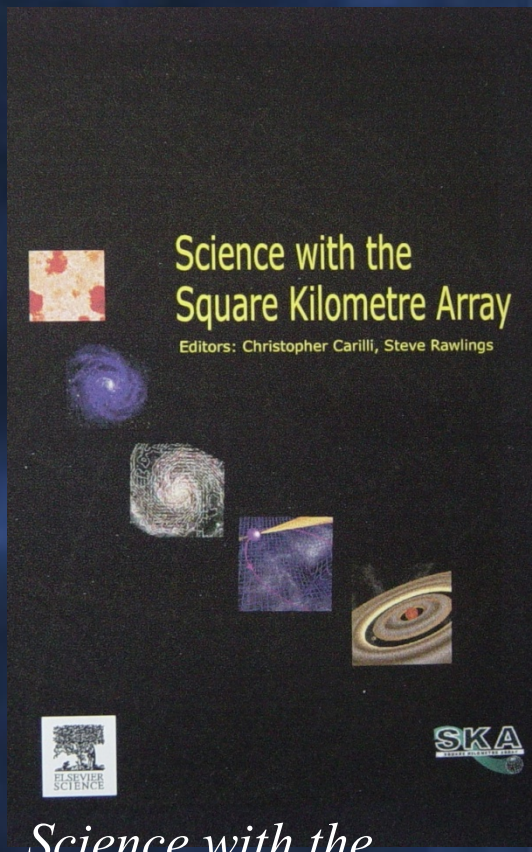
FUNDAMENTAL FORCES

- Pulsars, General Relativity & gravitational waves

- Origin & evolution of cosmic magnetism

NEW PHENOMENA (EXPLORATION OF THE UNKNOWN)

- Transients

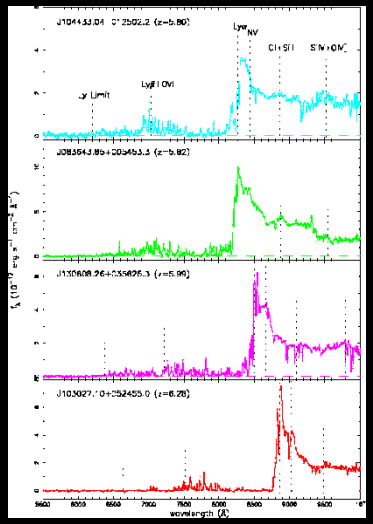


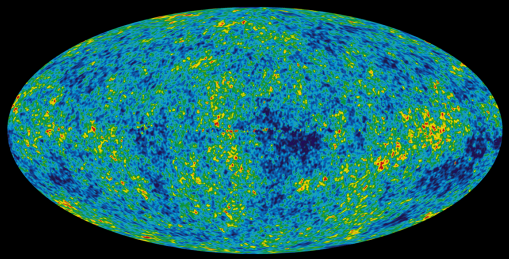
Science with the Square Kilometre Array

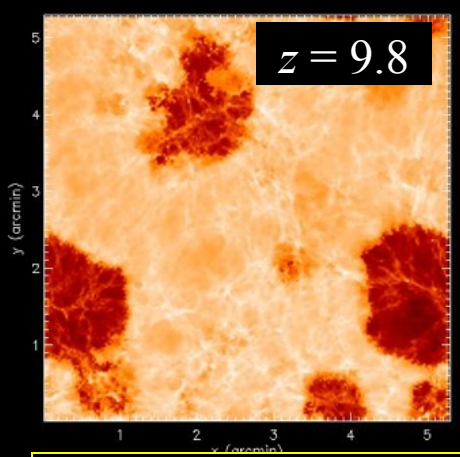
(2004, eds. C. Carilli & S. Rawlings, *New Astron. Rev.*, **48**)

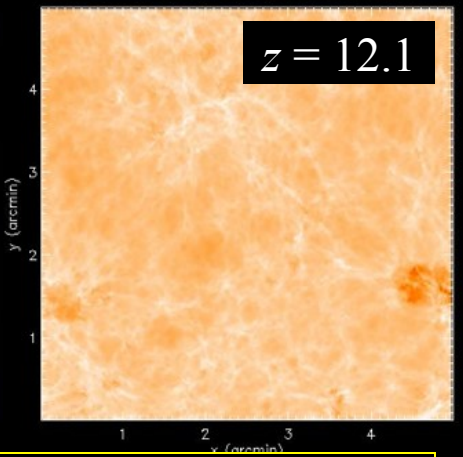
Epoch of Reionization

Universe made rapid transition from largely neutral to largely ionized 400 Myr to 1 Gyr after the Big Bang









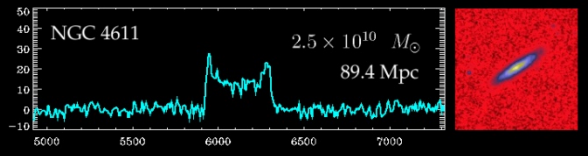
SKA objective: Image the transition in the InterGalactic Medium in the neutral hydrogen (21-cm) spectral line

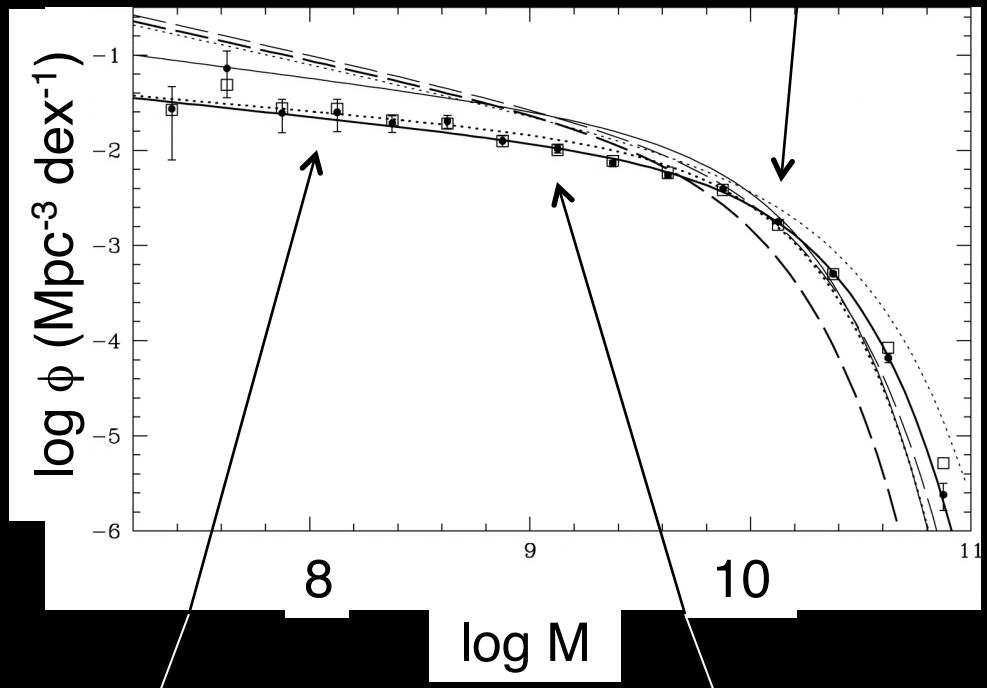
- Gunn-Peterson trough in high-z quasars
- Electron scattering opacity in CMB analysis

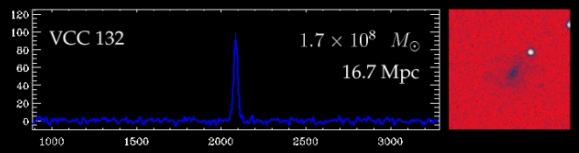
Galaxy Assembly & Evolution

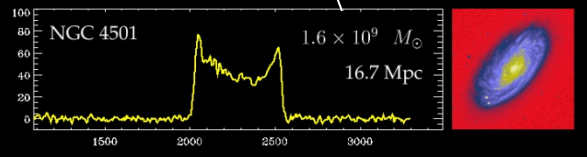
H I is the raw material for galaxies and star formation

- How do galaxies turn gas into stars?
- How does gas content vary with
  - Shape and size;
  - Time after the Big Bang;
  - Environment;
  - Mergers;
  - Feedback;
  - …



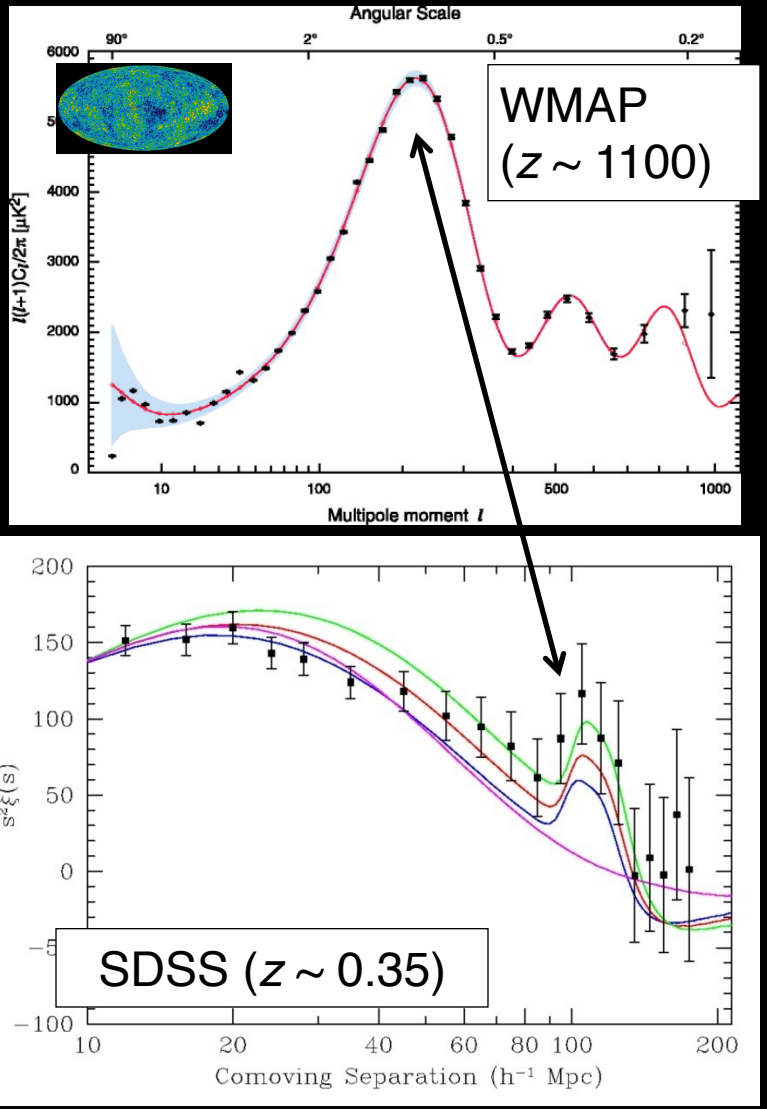




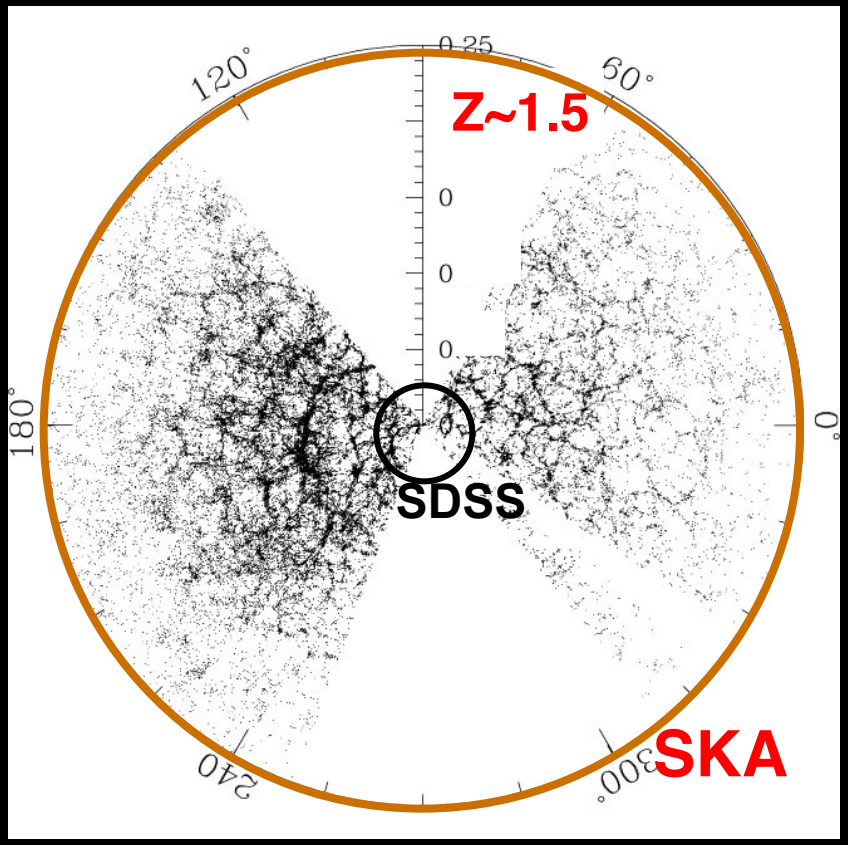


The expansion of the universe is accelerating. Why?

- Measured using "standard candles" and "standard rulers"
- Candle: Type Ia supernova
- Ruler: scale size of plasma acoustic oscillations in early Universe, frozen in at the time of recombination



SKA and Dark Energy

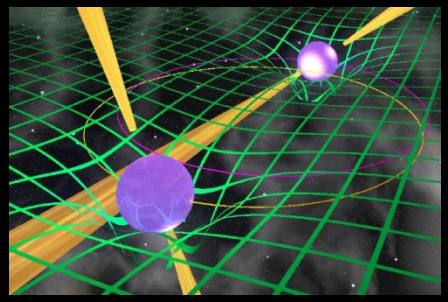


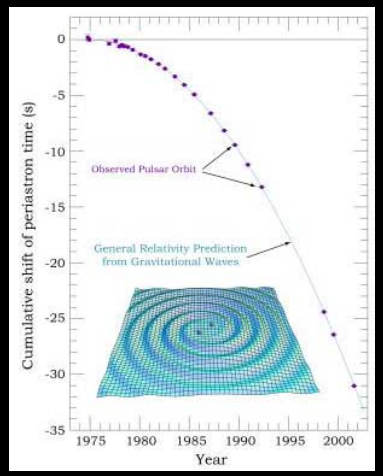
- Next-generation goal:
  - Survey large volume
  - Slice into redshift bins
  - Detect BAOs in each *z* bin

- SDSS surveyed ~ 1 Gpc^3
  One redshift bin ~ 0.35
- SKA targeting 100 Gpc^3 (z >~1.5)
- A billion H I galaxies
  - Intrinsically spectroscopic survey
  - Different biases than LSST, Euclid/WFIRST

Did Einstein Have the Last Word on Gravity?

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = 8\pi G T_{\mu\nu}/c^4$$

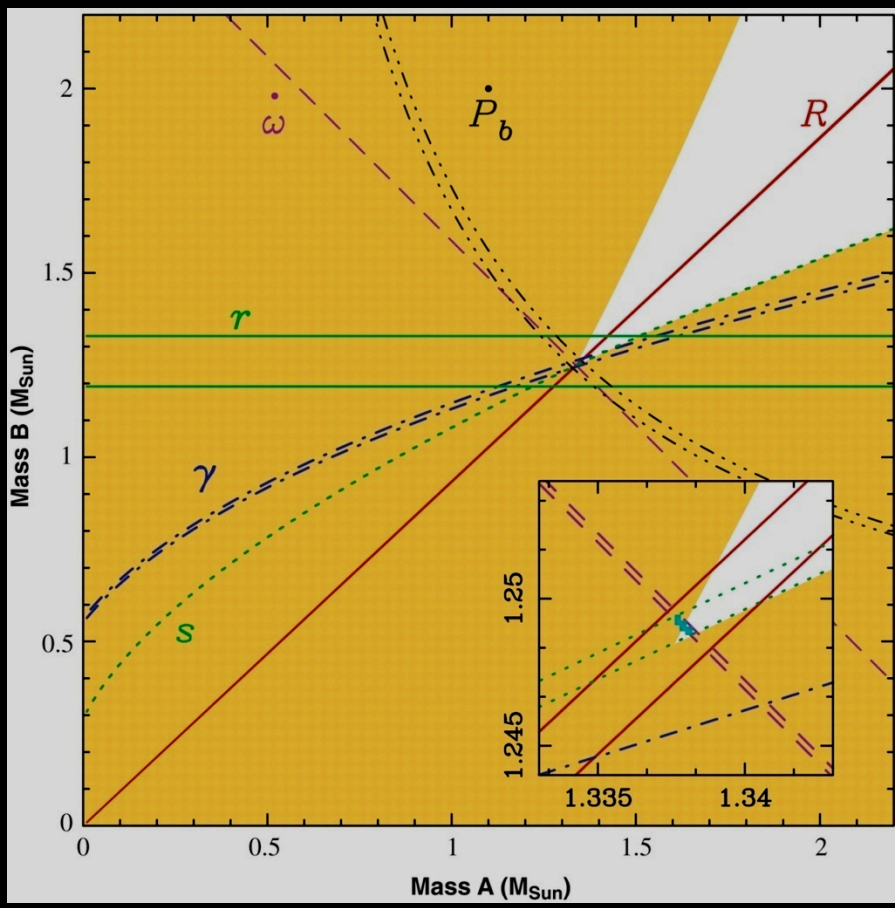




- Relativistic binaries probe
  1. Equivalence principle
  2. Strong-field tests of gravity
- Only neutron star-neutron star binaries known

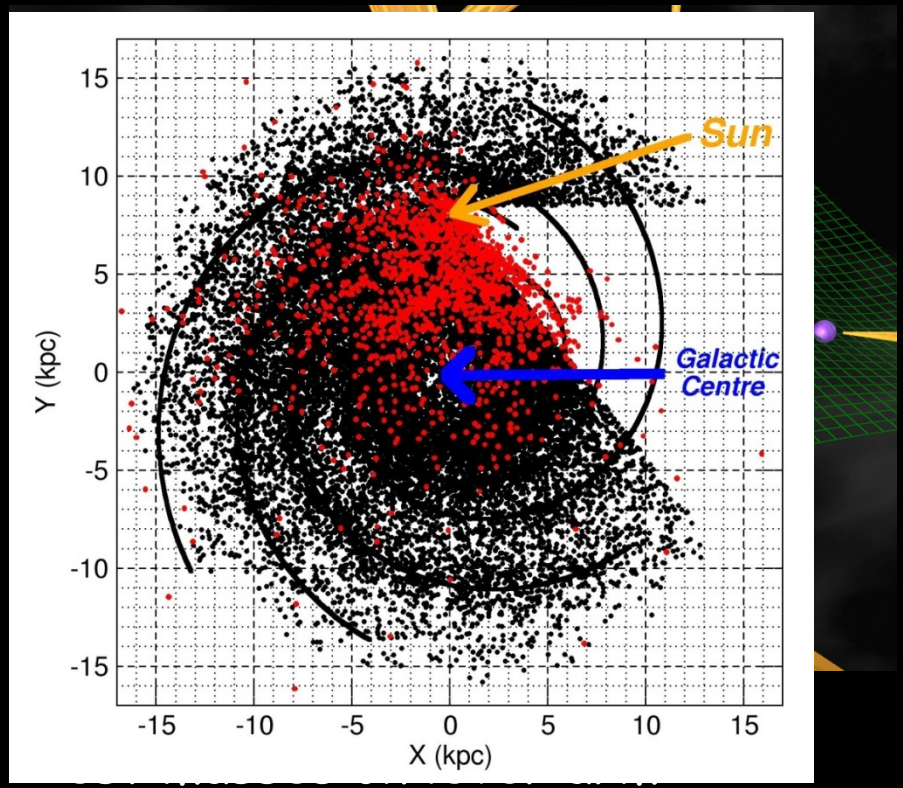
  Black hole-neutron star binaries?

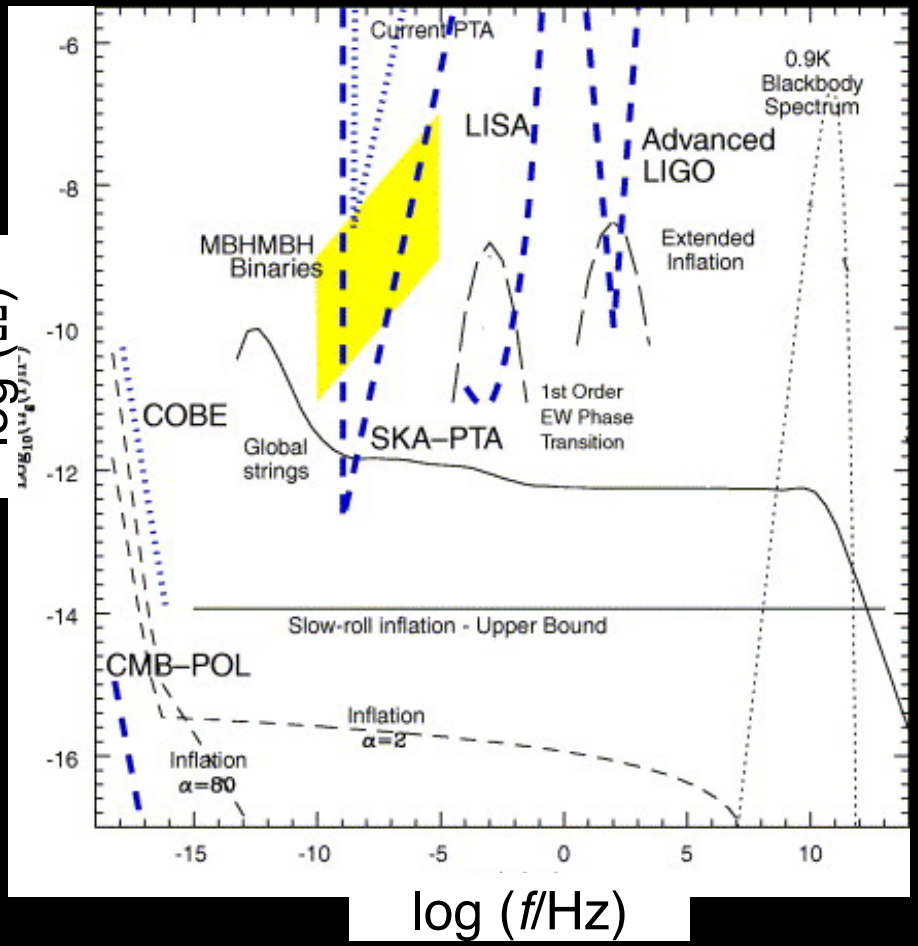
PSR J0737-3039



Kramer et al.

SKA: Gravitational Wave Detector

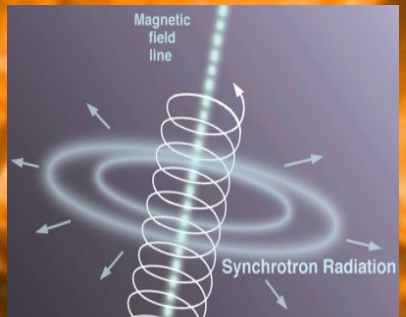


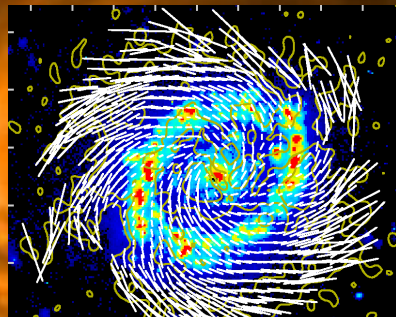


- Pulsar Timing Array = freely-falling millisecond pulsars
- LIGO = suspended mirrors
- LISA = freely-falling masses in spacecraft

Cosmic Magnetism

- Unique insight into the Magnetic Universe
- Origin of Cosmic Magnetism
- Role in the formation of structure
- Cloud collapse / star formation
- Stellar activity / stellar outflows
- ISM turbulence / gas motions
- Stability of galactic disks
- Acceleration / propagation/ confinement of cosmic rays
- Heating in galaxy clusters
- AGNs / jets/ blackhole IGM feedback

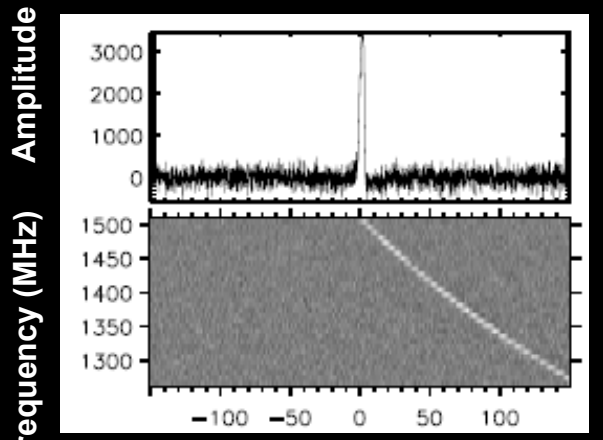




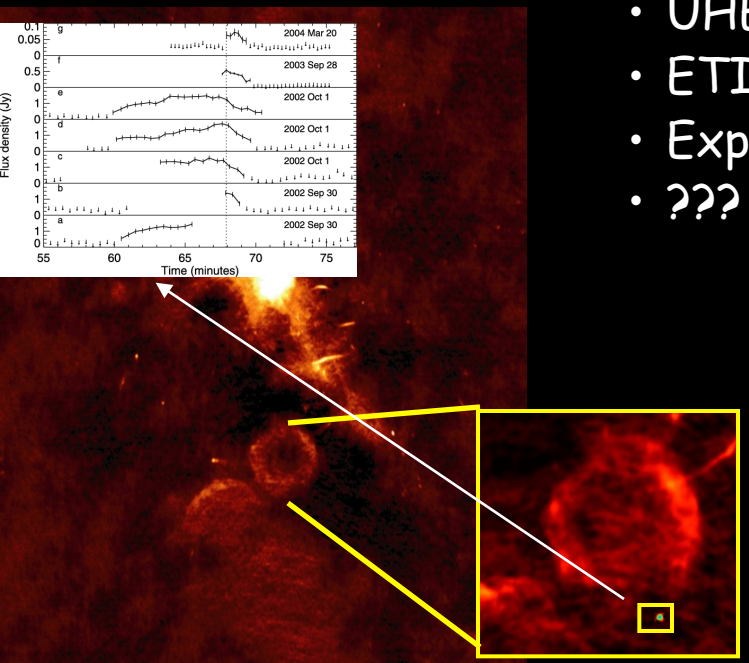
The Dynamic Radio Sky

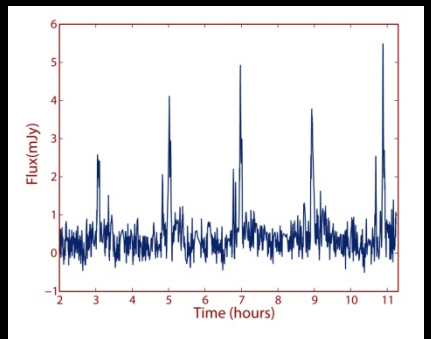
- Neutron stars
  - Magnetars
  - Giant pulses
  - Short GRBs?

- GRBs (g-ray loud; g-ray quiet?)
  - Afterglows
  - Prompt emission?
- Sub-stellar objects
  - Brown dwarfs
  - Extrasolar planets?
- Microquasars
- Scintillation
- UHECRs
- ETI
- Exploding black holes
- ???



Rotating Radio Transients (RRATS)

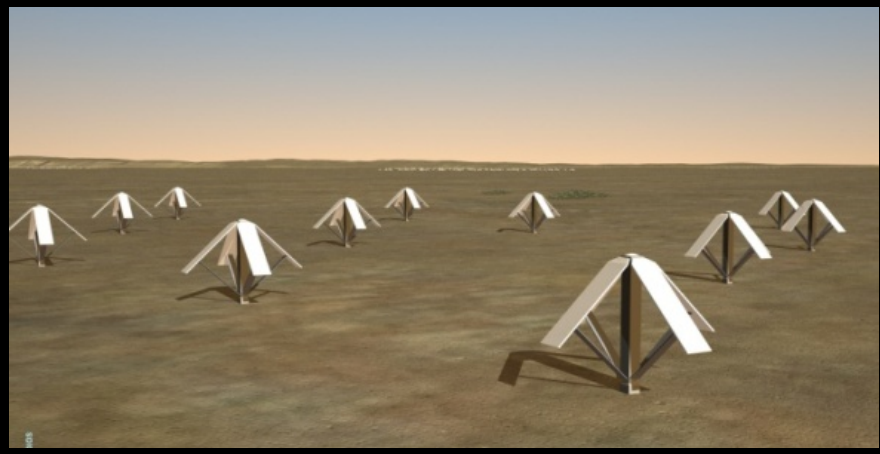




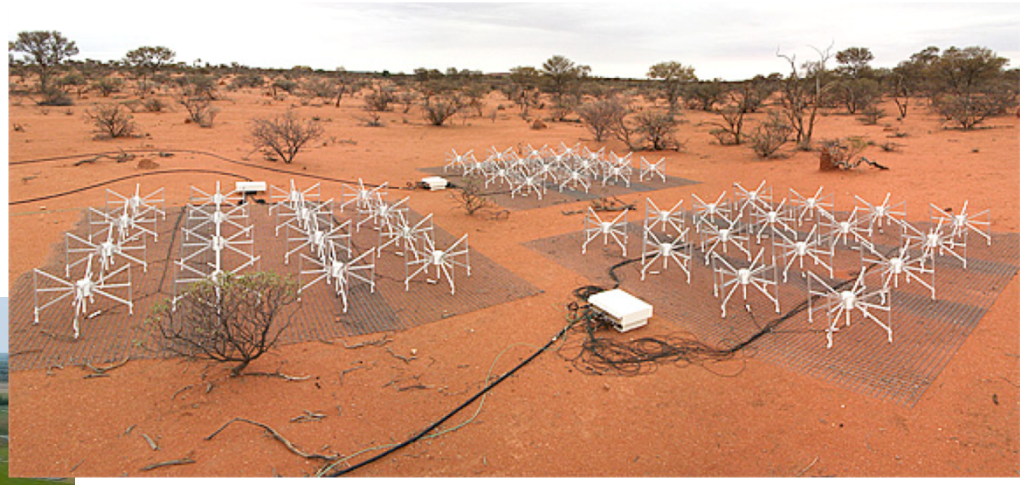
Pulsating Brown Dwarfs

Technical Requirements Snapshot

Wavelength (Frequency)	1 cm–4 m (0.07–25+ GHz)
Sensitivity	A_{eff}/T_{sys} ~ 10000 (10 nJy, 1000 h)
Field of view	1 deg^2 or larger (@ 1 GHz)
Survey speed	~ 10^{10} deg^2 m^4 K^{-2} (100 Gpc^3 survey of H I to $z > 1.5$)



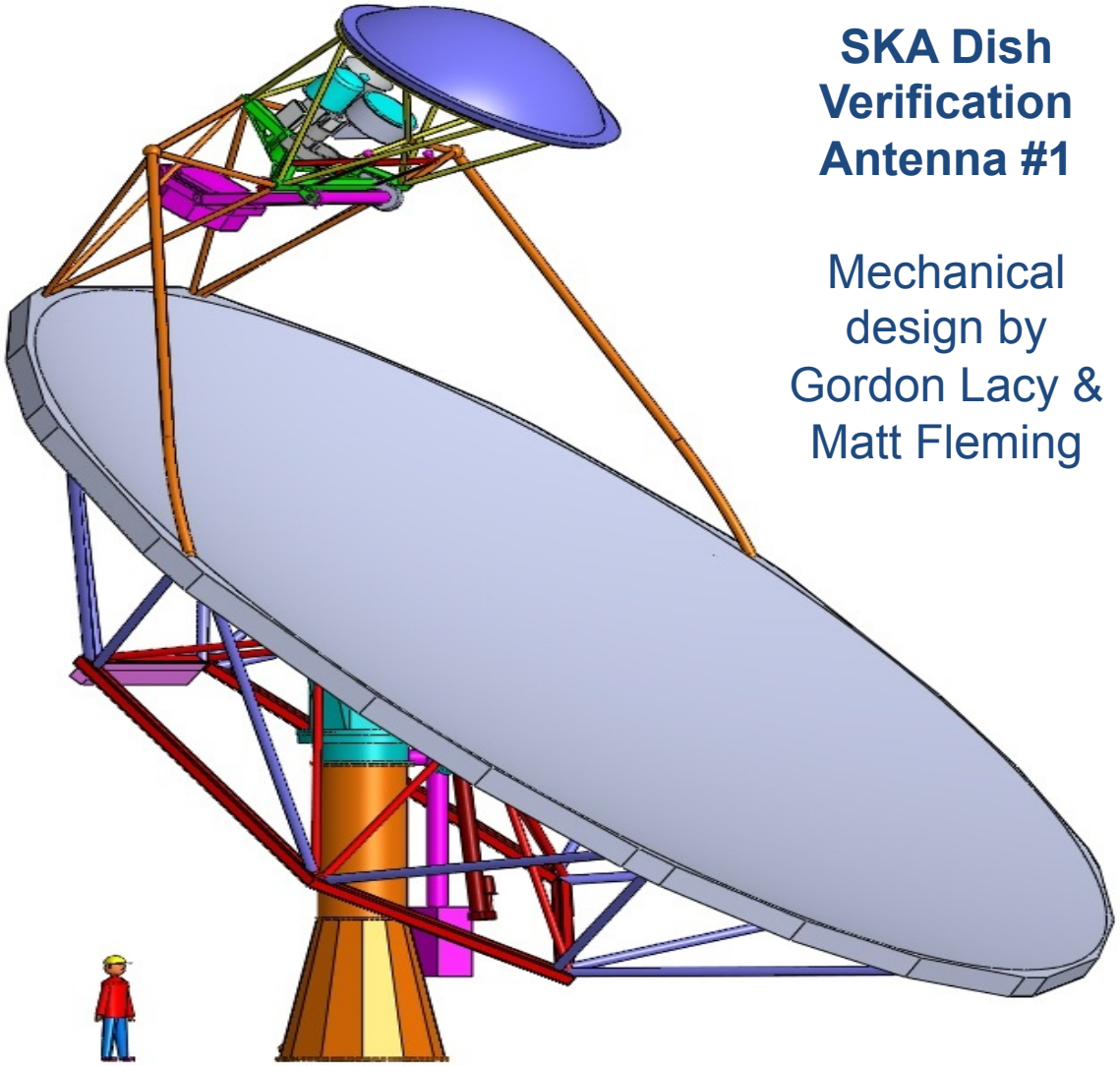
Baseline design component:
Low frequency aperture arrays



MWA (Australia, India, USA)

LOFAR (Netherlands et al)

Baseline design component:
Dishes + single pixel feeds

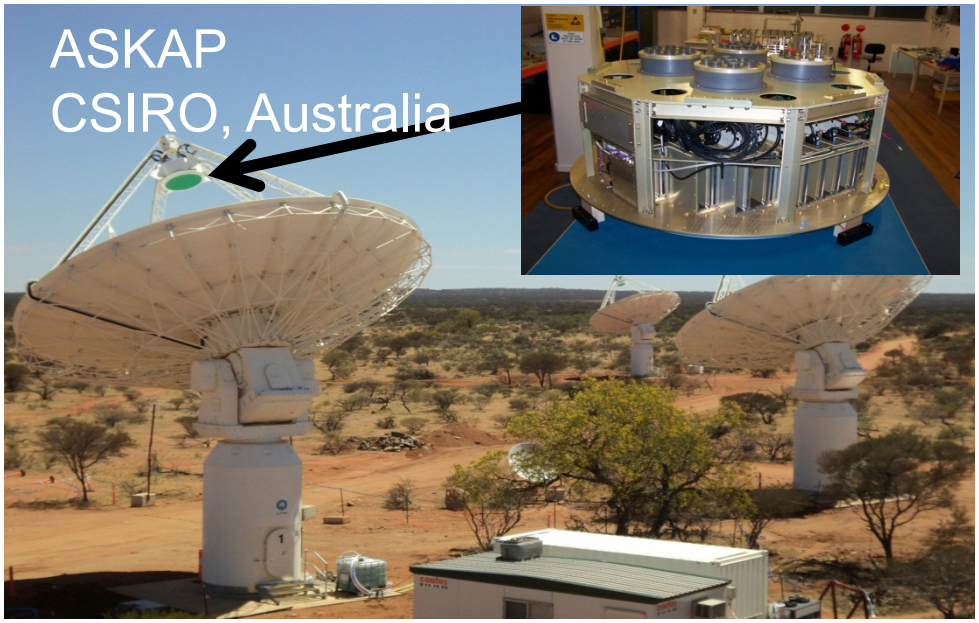


SKA Dish Verification Antenna #1

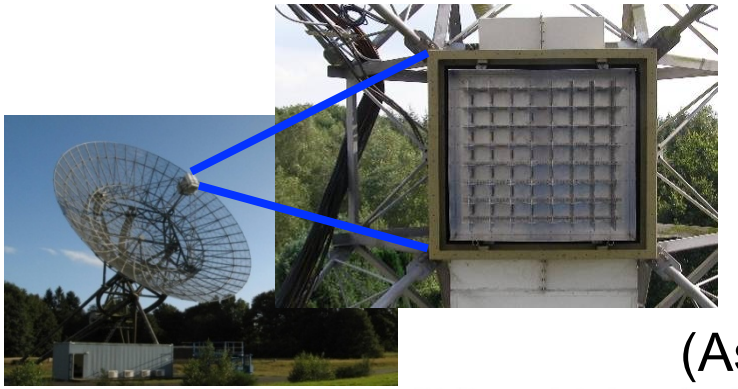
Mechanical design by Gordon Lacy & Matt Fleming

st radio telescope

Advanced Instrumentation Program:
dishes+multi-pixel feeds



DRAO
Canada

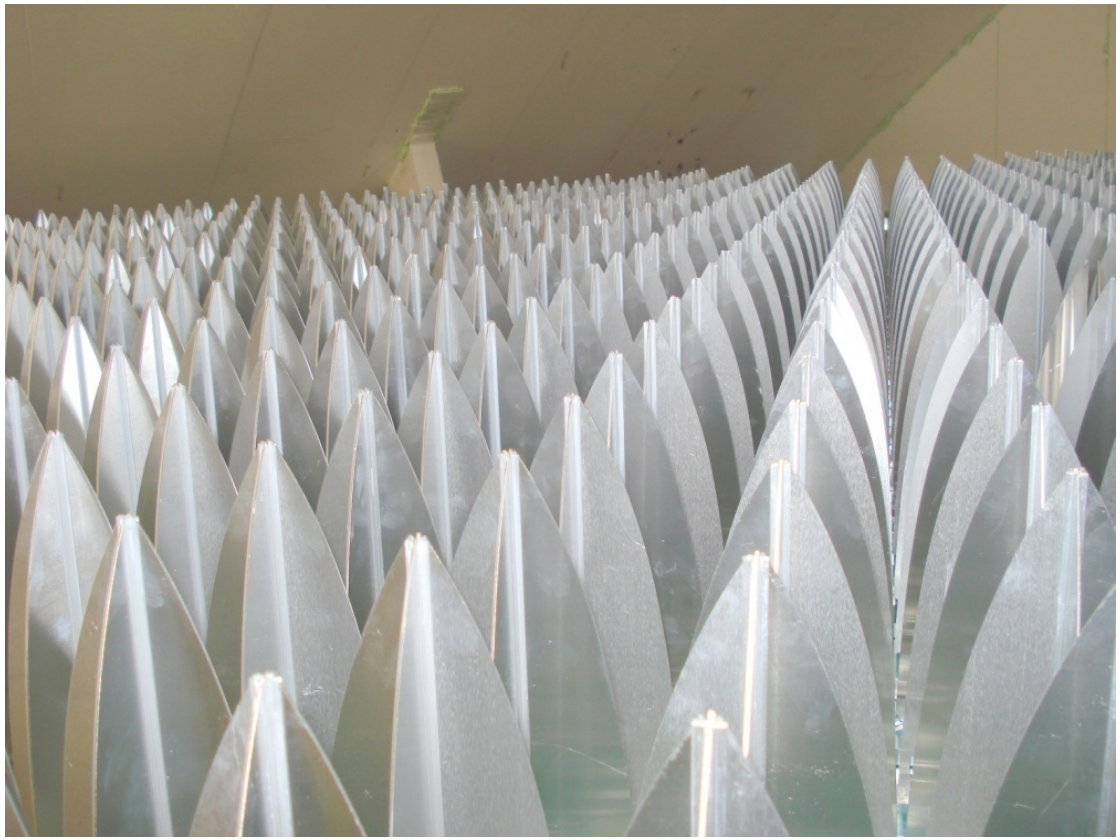


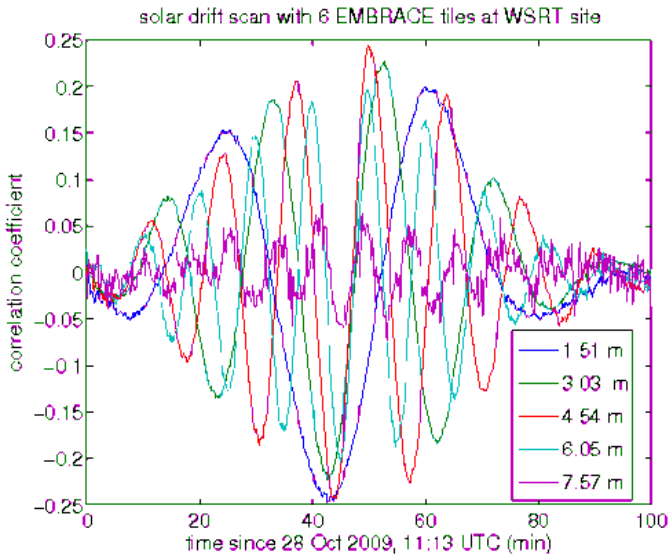
APERTIF
(Astron, NL)

Exploring the Universe with the world's largest radio telescope

Advanced Instrumentation Program:
mid-frequency aperture array

NL-UK





Industry already involved in production.

First Fringes

Exploring the Universe with the world's largest radio telescope

Location

"SKA Observatory" with two sites

- SKA-low (aperture array) in Australia

  SKA-mid (dish array) in Southern Africa, incorporating MeerKAT

  SKA_1 survey instrument in Australia, incorporating ASKAP

  (SKA_2 aperture array in South Africa)

- Incorporates SKA pre-cursor telescopes in South Africa and Australia in SKA Phase 1 to maximise initial science return

Schedule

- Preparatory phase (current phase)
- **Pre-construction phase (production readiness)**
- SKA1 construction, verification, commissioning, acceptance, integration & first science
- SKA2 construction, commissioning, acceptance, integration & first science
- SKA Operations

SKA Organisation

- Company limited by guarantee in the UK
- Owned by funding agencies and government departments in
  - Australia
  - Canada
  - China
  - Italy
  - Netherlands
  - New Zealand
  - South Africa
  - Sweden
  - UK
  - (Germany, India)
- Headquarters located at Jodrell Bank from next Monday

UK and the SKA

- Financial support from the STFC (2M£/yr)
- STFC Chief Executive is Chair of the Board of the SKA Organisation
- Manchester, Cambridge and Oxford provide the academic backbone of the UK involvement
- Industry will play a major role

U of Manchester and the SKA

- new building at Jodrell Bank for SKA Headquarters

adio telescope

U of Manchester and the SKA

- new building at Jodrell Bank for SKA Headquarters

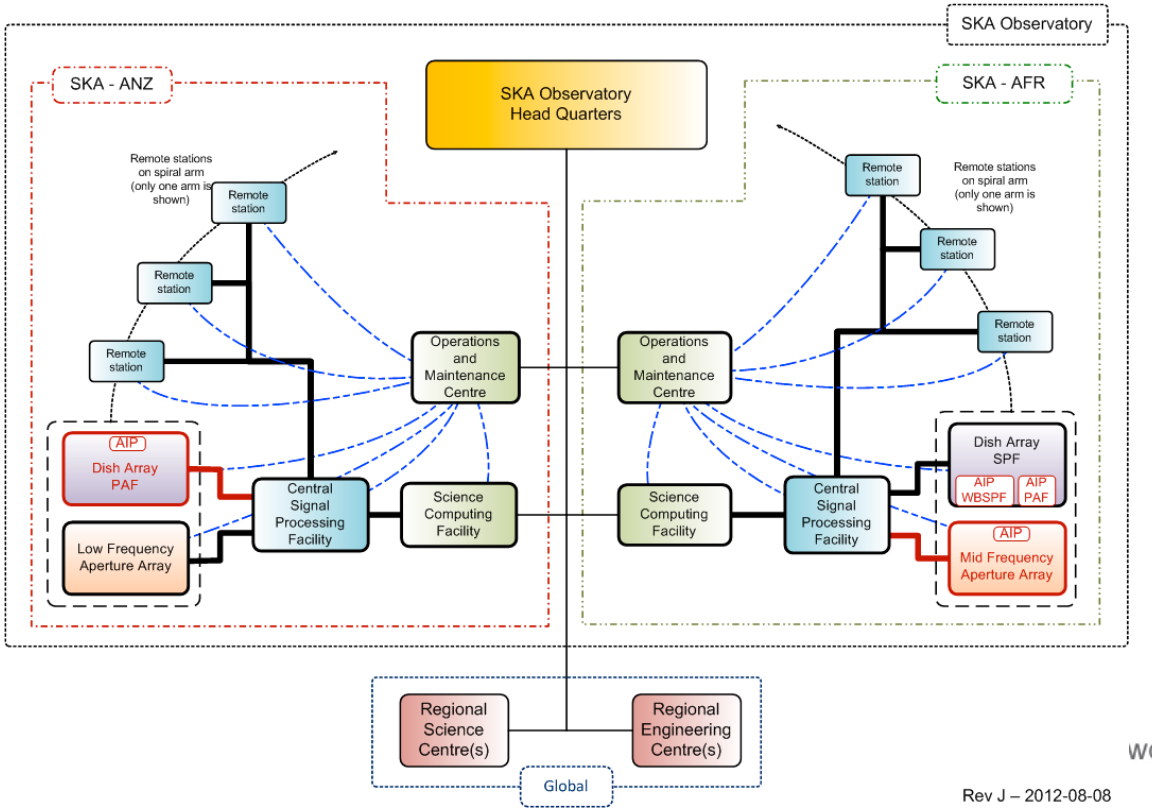
- established the SKA Group in JBCA to play a leading global role in the science and engineering of the SKA

SKA science in Manchester

- Cosmology
  - Weak gravitational lensing
  - Gravitational lenses and dark matter
- Pulsars
  - Searching
  - Timing
- Galactic evolution
  - Star formation
  - Active Galactic Nuclei
- Magnetism

SKA engineering in Manchester

- Synchronisation & timing (lead)
- Signal and data transport (lead)



Signal Transport & Networks for the SKA

Data Network	• For transporting astronomical signals to a central processing facility (CPF)
Processing links network	• For transporting data products between the Correlator and the HPC
External Network	• For transporting data products to global regional science centres
A Monitor & Control Network (M&C)	• Including comms and required redundancy
Synch & Timing Network	• For the distribution of local oscillator signals for clocks and down converters.
Network Infrastructure	• Serves all those services carried over a fibre optic network

SKA engineering in Manchester

- Synchronisation & timing
- Signal and data transport
- Non-imaging processing for pulsars and transients
  - Pulsar search
- Aperture array element design (EEE)
- Aperture array calibration
- LNA development (EEE)

SKA Group

- Richard Schilizzi – Head of Group
- Lecturer 1 – science, instrumentation
- Lecturer 2 – science, instrumentation
- Lecturer 3 – science, instrumentation
- Althea Wilkinson – Project Manager
- Richard Oberland – Optical Engineer
- Paul Carr – System Engineer
- Richard Whitaker – Engineer
- Vacancy – Engineer
- Aziz Ahmedsaid – RA in non-imaging processing (from May 2013)
- David Zhang – RA in AA element design (EEE)
- Ahmed El-Maradeh – RA in AA element design (EEE)
- Ming Yang – RF engineer (EEE)

+ 11-12 associated academic staff, and students (to come)