Radio Cosmology at KICC

Unveiling the infant Universe with radio experiments and mega observatories

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Cavendish Radio Cosmology

KICC mini symposium

15-09-22
Overview

- 21-cm cosmology
- REACH and HERA
- SKA
- Space-based radio cosmology
21-cm cosmology

Cosmic Dawn

Epoch of Re-ionization

Galaxy observations

21-cm line

Cosmic Dawn

Epoch of Re-ionization

Galaxy observations

21-cm line
21-cm line

\[ T_S = \text{HI spin temperature, } \lambda = 21 \text{ cm} \]

\[ T_\gamma = \text{Background temperature, eg. CMB} \]

\[ T_K = \text{Gas Kinetic temperature} \]

\[ T_S (\text{CMB}) \]

Radiative transfer

\[ T_b(z) \approx \tau(T_S - T_\gamma)/(1 + z) \]
Collisions

Ly-α

X-rays

UV reionization

Time after Big Bang [Years]

Redshift = 160  80  40  20  15  14  13  12  11  10  9  8  7

0  50  100  150  200

Brightness [mK]

First galaxies form

Reionization begins

Reionization ends

Heating begins

Cosmic time

“absorption”

“emission”

Freqency [MHz]
Extreme Challenge

Instrumental effects are key

Averaged foregrounds

Cosmological signal

Experimental/Observational challenge
Roadmap for Cavendish Radio Cosmology

- **SKA1 development**
  - Early science with experiments
    - 21-cm statistics
  - SKA1 science exploitation
    - 21-cm TOMOGRAPHY

- **SKA2 development**
  - SKA2 science exploitation
    - DARK ENERGY

- **Space-based radio cosmology**
  - DARK MATTER

Field timeline:

- **2020s**
- **2030s**
The EDES detection of 2018

- **Hotter background temperature** $T_y$?
  - eg. Radio loud blackholes, radiative decay of particles, annihilating dark matter, super-conducting cosmic string?

- **Colder gas temperature** $T_k$?
  - eg. Dark-matter – Baryonic matter interactions?

- **Systematics?**

Bowman, Rogers, et al., 2018
de Lera Acedo et al., Nature Astronomy 2022
SKA in the UK

• 3 host countries: **UK (SKAO headquarters at Jodrell Bank), South Africa and Australia**

• **UK is the largest cash contributor**: £270m out of £1.7b (£1.1b construction and £0.6b - 10 years operation)

• **UK leads key work packages** (eg. Science processor – Cambridge)
SKA in Cambridge

• Leading 2 fundamental aspects of the design:
  • Science Data Processor (http://ska-sdp.org) – science ready products
  • Low Frequency Aperture Arrays (the “Cosmic Dawn” instrument)
Radio astronomy beyond Earth

- Key science goal: Pushing into the Dark Ages with 21-cm cosmology ($z > 30$)
- The Moon is back in the agenda of the space agencies
  - Low RFI?, no ionosphere
- Interferometers, dishes, satellites,...
Radio Cosmology from the Moon

- Dark Ages, 25 < z < 150
- Cost-efficient CubeSat technology
- Observations from the far-side of Moon’s orbit in late 20s
  - Lead: KICC
  - Partners: UK, US

- Dark Ages, 25 < z < 150
- Radio interferometer
- Observations from the far-side of Moon’s surface in early 30s
  - Lead: NL/ESA
  - Partners: ESA, UK (KICC)
Conclusions

• 2\textsuperscript{nd} golden age of radio astronomy
• KICC/Cambridge leads in several fronts
• From small experiments to mega observatories
• Next 15-20 years: mega radio-observatories SKA and NgVLA
  • “discovery” machines: Big-data, all-sky, all-digital
  • super sensitivity and resolution
• In the 30s and 40s: radio astronomy from space/Moon
End

• Thank you!