Global Imprints from Nascent Atoms to Now

GINAN collaboration

Ravi March 2021

The GINAN collaboration aims at detection of global spectral distortions in the radio background

[At long wavelengths - using custom built radiometers - to detect redshifted 21-cm spectral distortions from Cosmic Dawn & Epoch of Reionization]

<u>At cm wavelengths:</u>

- Begin exploring the global spectrum using ATCA antennas and auto-correlation spectra - for which BIGCAT is a fantastic backend!

- Towards designing a custom array of feeds - for which BIGCAT or a scaled down copy could be the backend.

The science case:

- Constraints on DM: from constraints on global radio spectral distortions arising from DM decay - as an intermediate goal
- Towards detection of inevitable spectral distortions from cosmological recombination

(Will expand on both these in following slides)

The requirements:

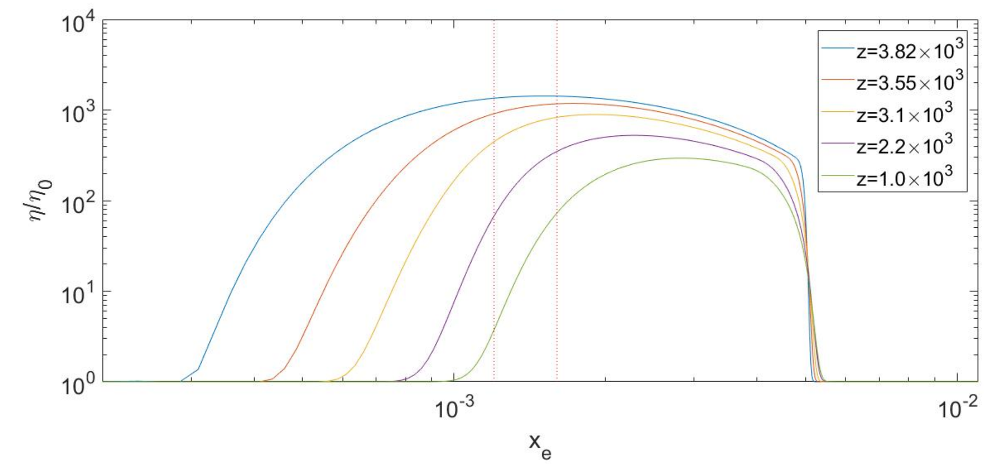
- Total power spectral measurements
- Precision bandpass calibration of channel-to-channel gains; does not require absolute calibration.
- Ultra-wide fractional bandwidth - at least an octave bandwidth at cm wavelengths.

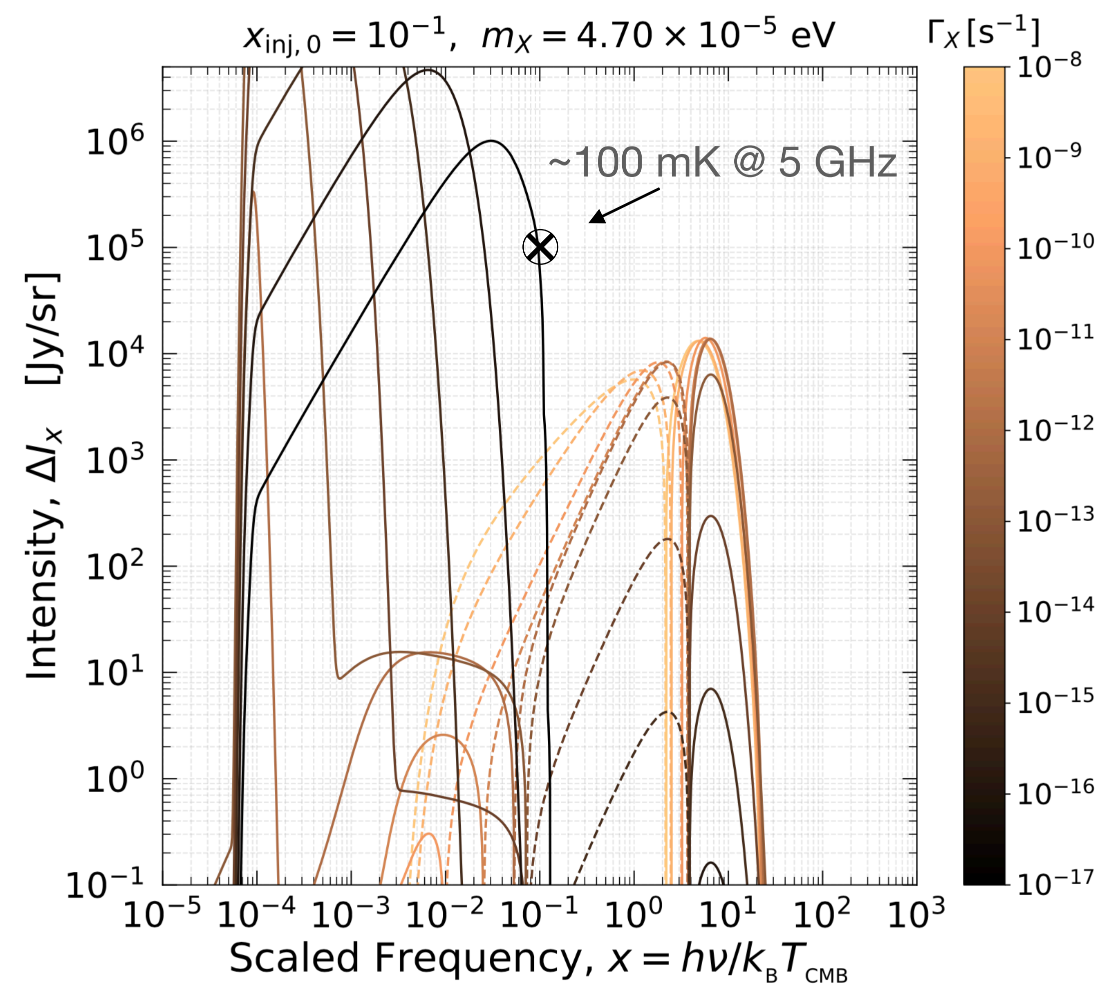
The opportunity:

- ATCA has six antennas - two polarisations - twelve radiometers observing in parallel.
- 4 cm wideband band feed allows for observing in a band 4-12 GHz that exceeds an octave.
- On-axis optics.
- IF filters + Jimble + GPUs = BIGCAT will be equivalent of a hybrid spectrometer of 8 GHz instantaneous bandwidth.
- With high spectral resolution for RFI excision.
- ATCA has large antennas and best SEFD in the 4 cm band - essential for calibration in interferometer mode.

Spectral distortions from DM decay:

- Energy injection in the pre-recombination era, at redshifts $z < 10^5$, will survive to $z = 0$
- The CMB spectrum is well constrained in the COBE-FIRAS band, but less constrained at cm and longer wavelengths, allowing for energy injections at $x_e = h\nu/k_B T \ll 1$
- For example, the EDGES absorption at 78 MHz could be explained as arising from excess background at $x_e \approx 10^{-3}$.
- Any excess photon spectrum shifts to lower $x_e = h\nu/kT$ with Compton scattering, heating the electrons and causing y & μ distortions in CMB.
- Decay of NR DM particles - like axions - into a neutral massless particle + photon -> relatively sharp edge at $x_e = m_D c^2/(k_B T_z)$, which may be a detectable feature in cm-wavelength measurements of the global radio background.





[Brahma, Sethi, Sista JCAP12(2020)034]
[Bolliet, Chluba, Battye arXiv:2012.07292]

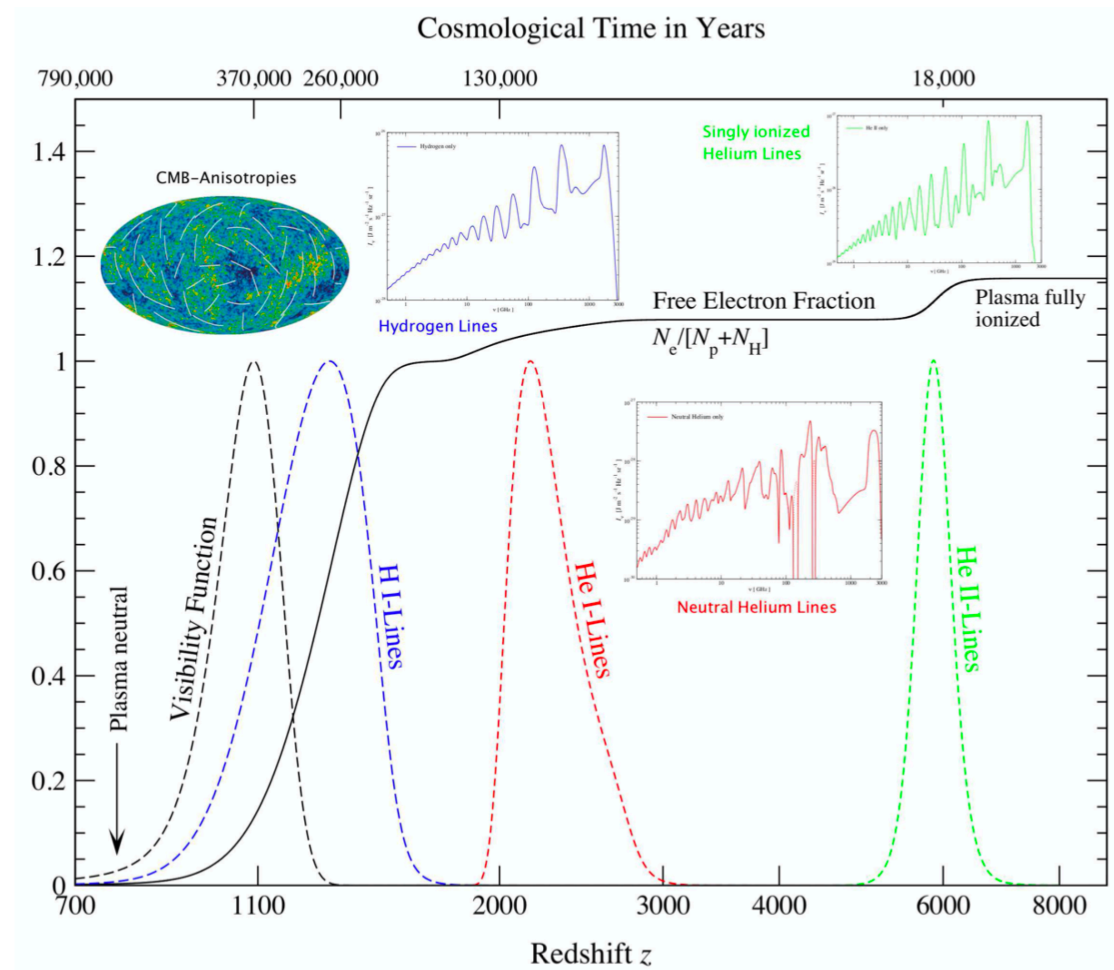
Spectral distortions from cosmological recombination:

These are inevitable distortions

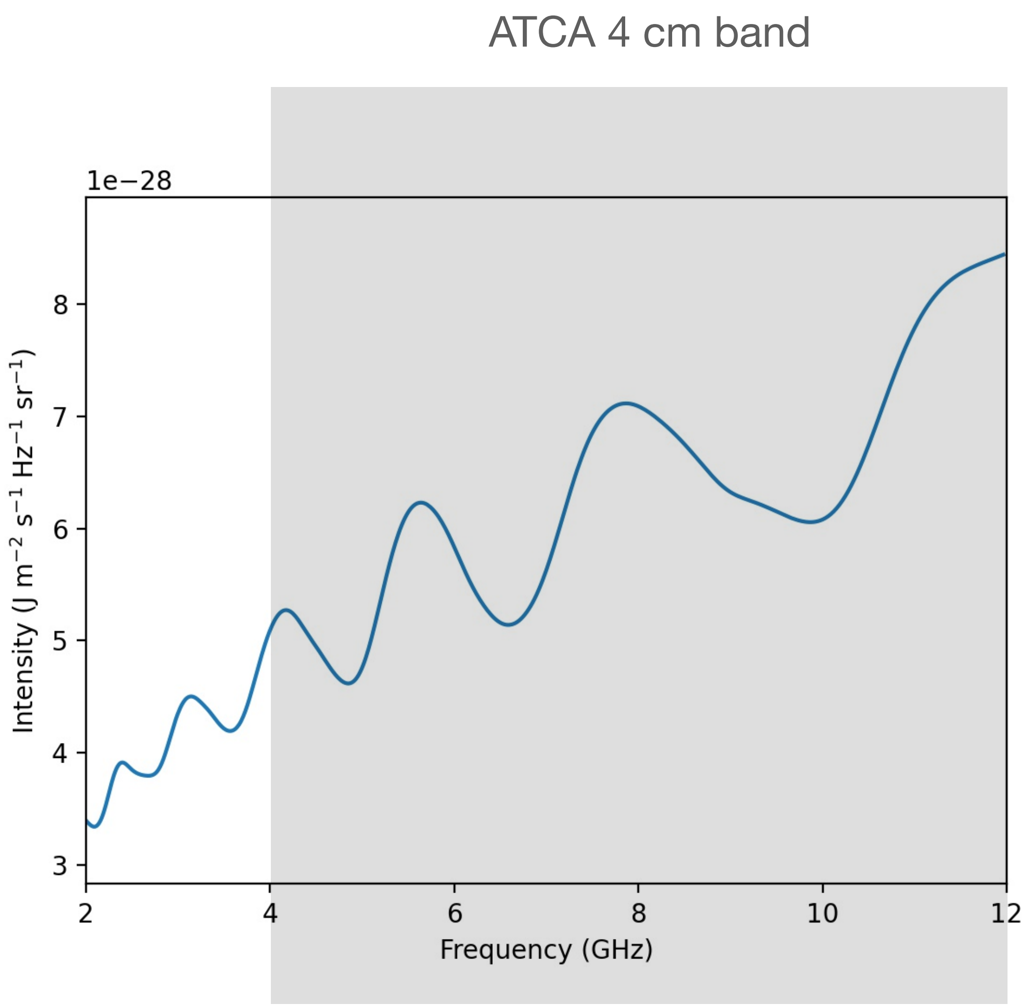
- which we do not expect to detect with ATCA -

but aim to detect with a custom-design feed array that would use a BIGCAT-clone as digital spectrometer.

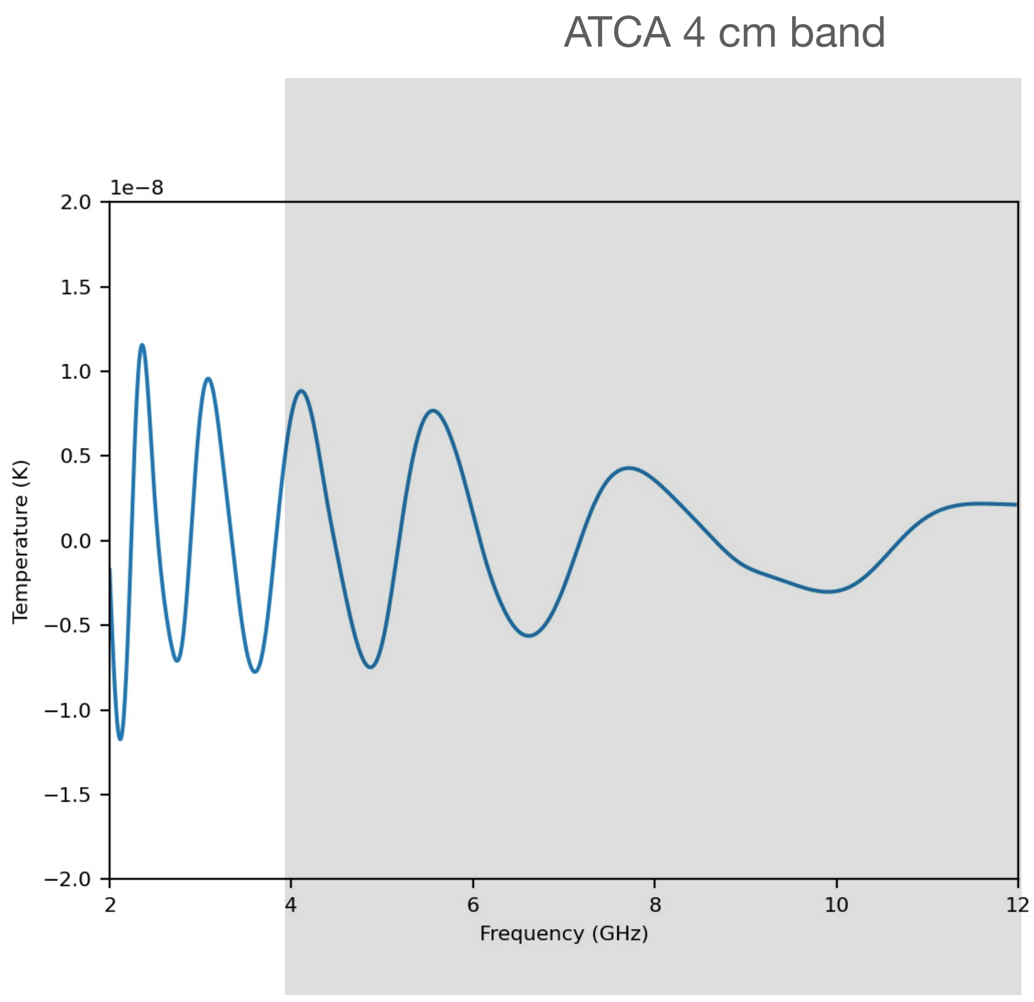
- HeIII-> HeII & HeII-> HeI recombination lines added to CMB at $z \leq 6000$
- HII -> HI recombination lines added to CMB at $z \sim 1000$
- These survive to Now because thermalisation processes are no longer effective in restoring the radiation to Planck form.
- Detection brings astrophysics to cosmology - probes physics of matter-radiation interactions beyond the last-scattering surface.
- Any energy release at earlier times causes y & μ and intermediate distortions, which are tough to detect because they are potentially confused by foreground y distortions from cosmic baryon evolution: and hence effect of early energy release on recombination predictions and line structure are a cleaner probe of physics beyond the last-scattering surface!



[Sunyaev & Chluba 2009 AN 330, p657]



ATCA 4 cm band
1e−28
Intensity (J m^{-2} s^{-1} Hz^{-1} sr^{-1})
Frequency (GHz)



ATCA 4 cm band
1e−8
Temperature (K)
Frequency (GHz)

Observing strategies:

GINAN collaboration proposes to trial and evolve observing and calibration strategies in pilot observations with the ATCA using CABB.
To be continued with BIGCAT.

With science use case of constraining decaying-DM candidates.

- Observing in hybrid arrays and using interferometer visibilities on strong sources to derive antenna bandpass solutions.
- Using the Moon as a block for calibration of receiver noise additives.
- Differencing between Moon and off-Moon (observing on a full Moon night and repeating the sky position on a subsequent New Moon night).
- Pointing with offsets from the centre of the Moon to mitigate spectral confusion from sidelobes sweeping past lunar limb across the band.
- Focus changes to mitigate antenna sidelobe response.

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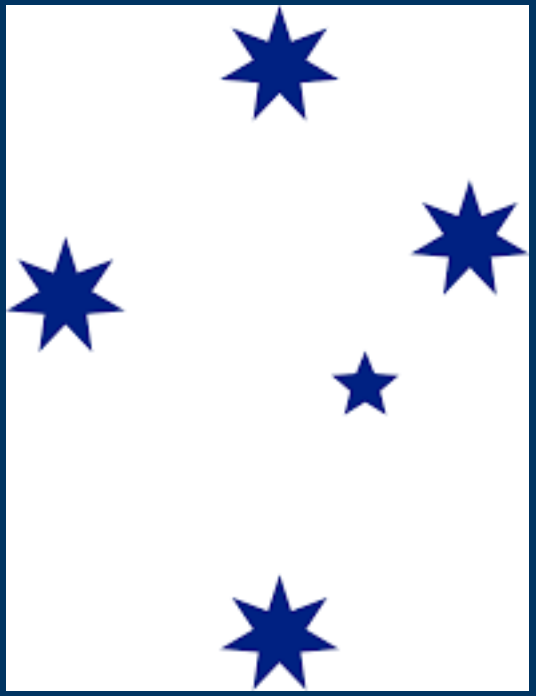

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