The Cosmic Radio Background

Foregrounds to the Epoch of Reionization

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Outline

Sources of the Cosmic Radio Background

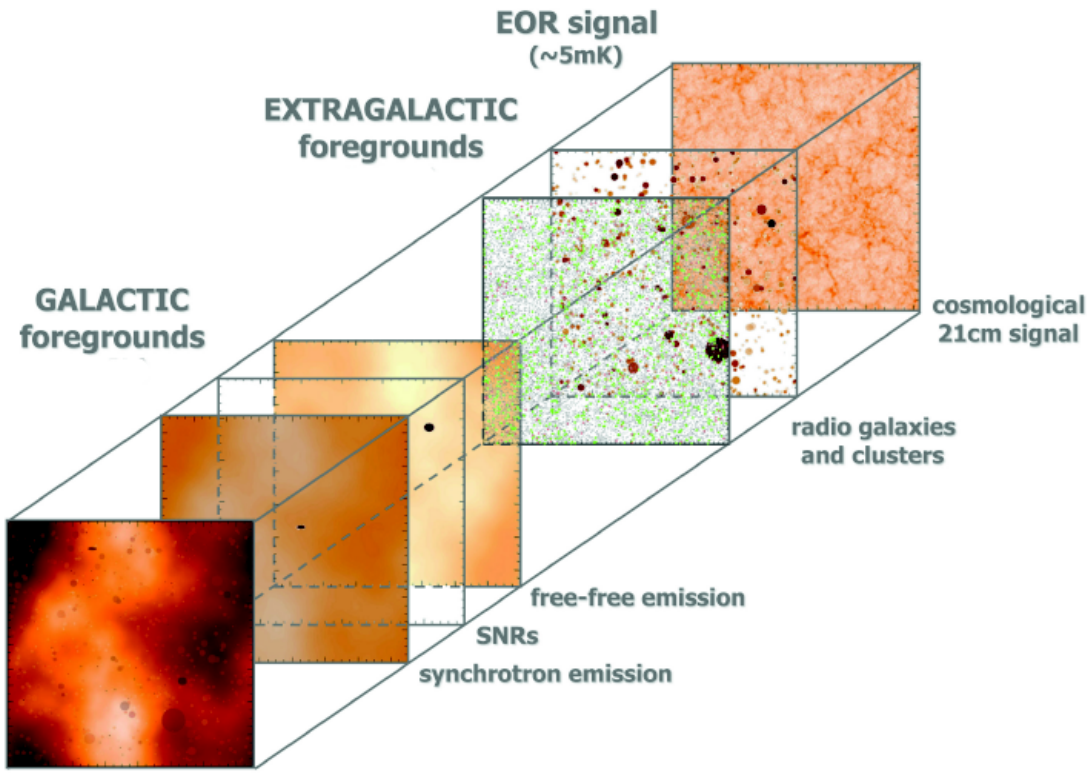


Figure: Components of the Cosmic Radio Background [Image credit, Jelić et al., 2008]

- Observations imply $T_{\mathrm{CRB}} \approx 20\mathrm{K}$ at 408 MHz
- Of the 20 K total background only ∼11 K is of known origin!

Sources of the Cosmic Radio Background

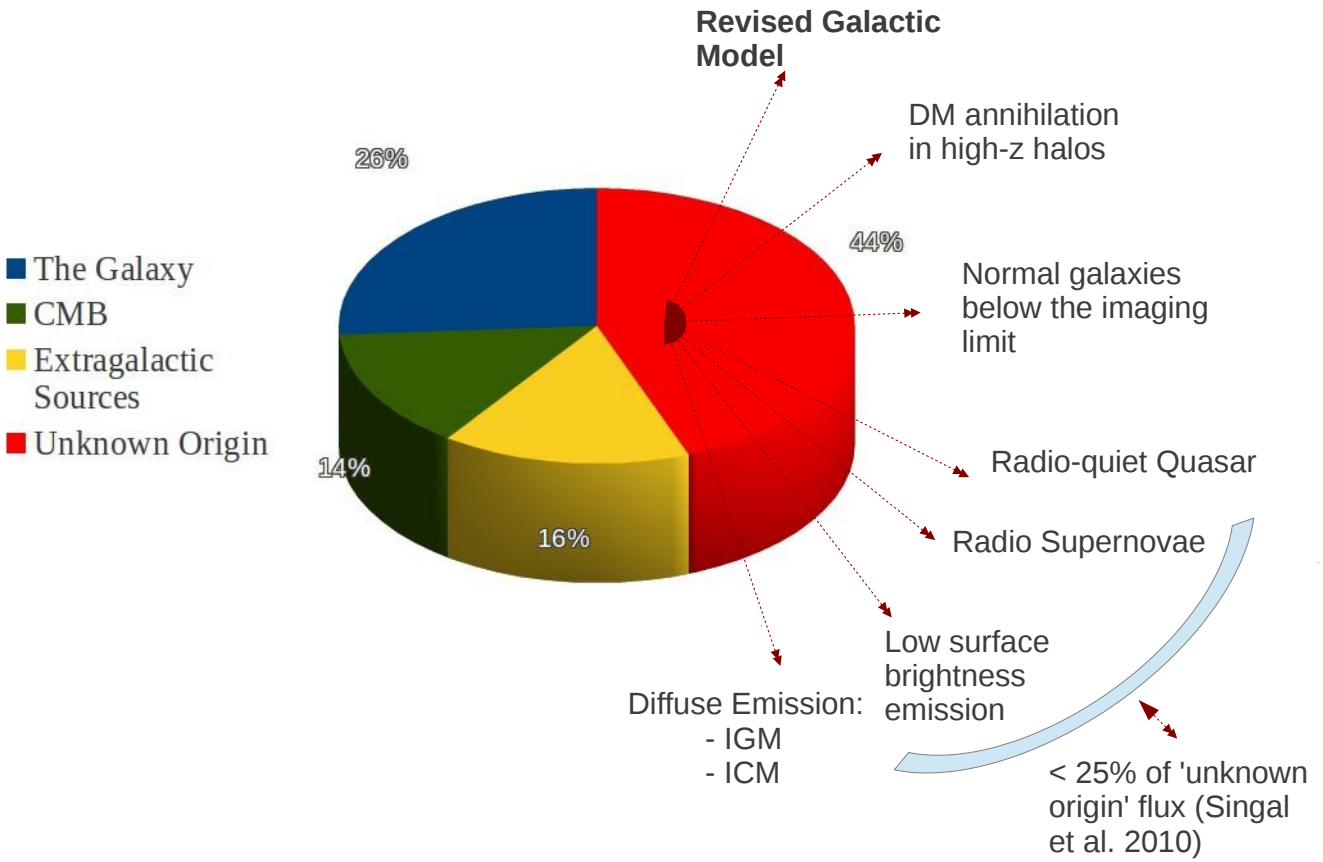


Figure: Source contributions to the ARCADE2 measured Cosmic Radio Background (excess emission with power-law energy spectral density $T_0 \left(\frac{\nu}{\nu_0}\right)^{-\beta}$ with $T_0 = 1.17$ K, $\nu_0 = 1$ GHz and $\beta = -2.6$ remains after subtraction of modelled Galactic emission, the CMB and catalogued extragalactic sources)

Contribution from catalogued sources

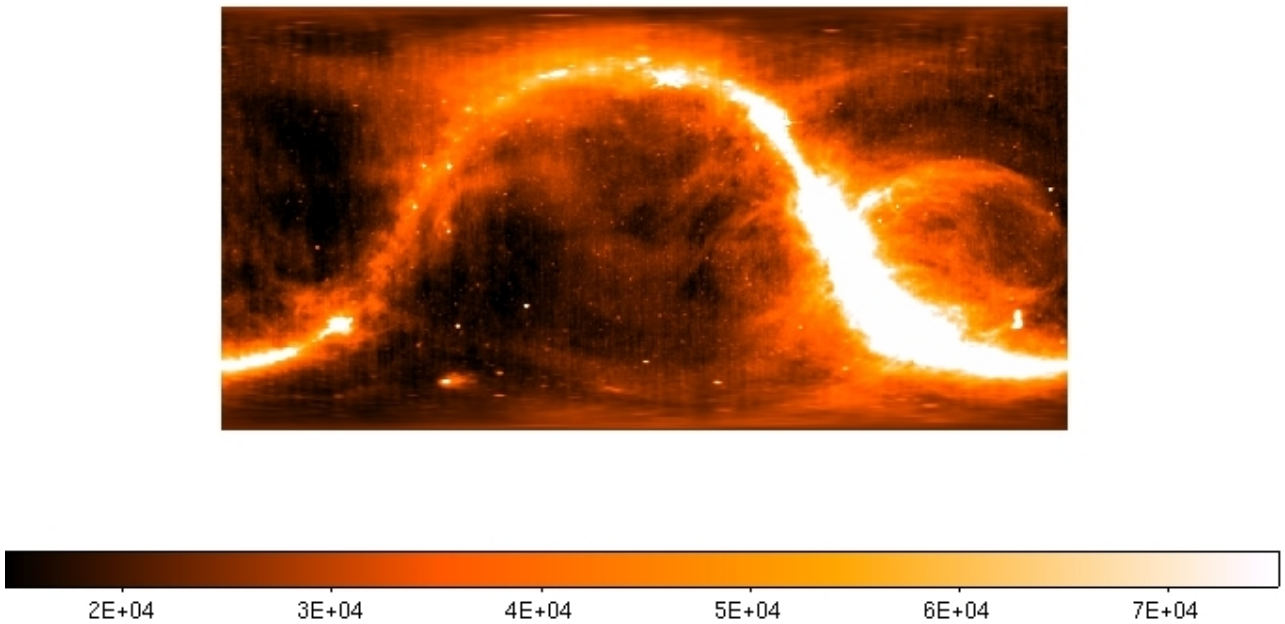


Figure: Haslam 408 MHz all-sky survey (Haslam et al. [1981]).

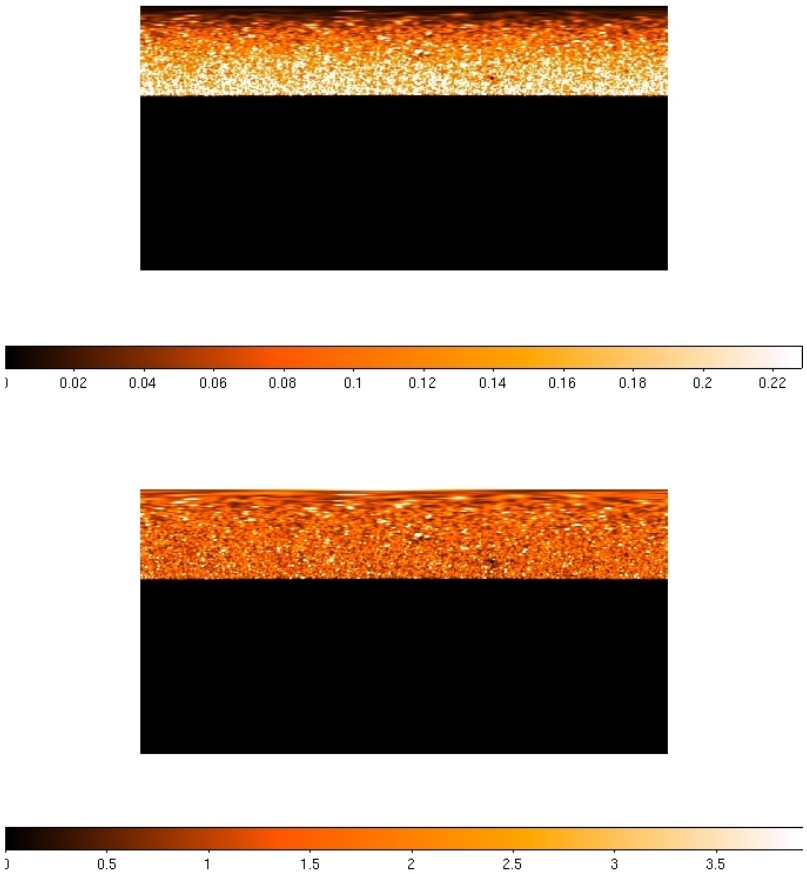
- Identify coldest region
- Calculate flux contribution to the brightness temperature from catalogued sources in this region
- This represents a lower limit on the catalogued source contribution to extragalactic emission

Flux-Density & Brightness temperature source maps

- Point source map of NVSS flux-densities smoothed to the $0.^{\circ}85 \times 0.^{\circ}85$ resolution on the Haslam map
- Conversion to brightness temperature via Rayleigh-Jeans relation:

$$I_\nu(T) = \frac{2\nu^2 k_B T_B}{c^2}$$

Figure: Smoothed flux-density and brightness temperature maps of NVSS sources extrapolated to 408 MHz



Catalogued source contribution to coldest region

- Coldest region 13.7 K at 408 MHz

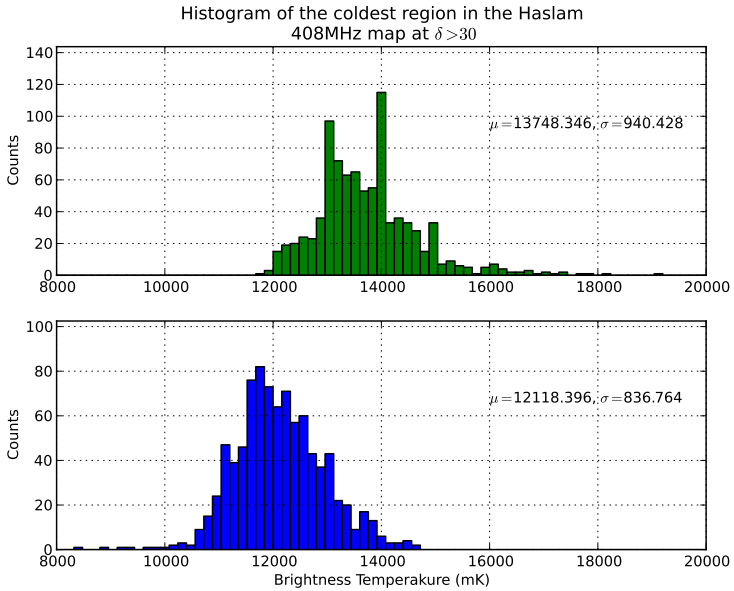
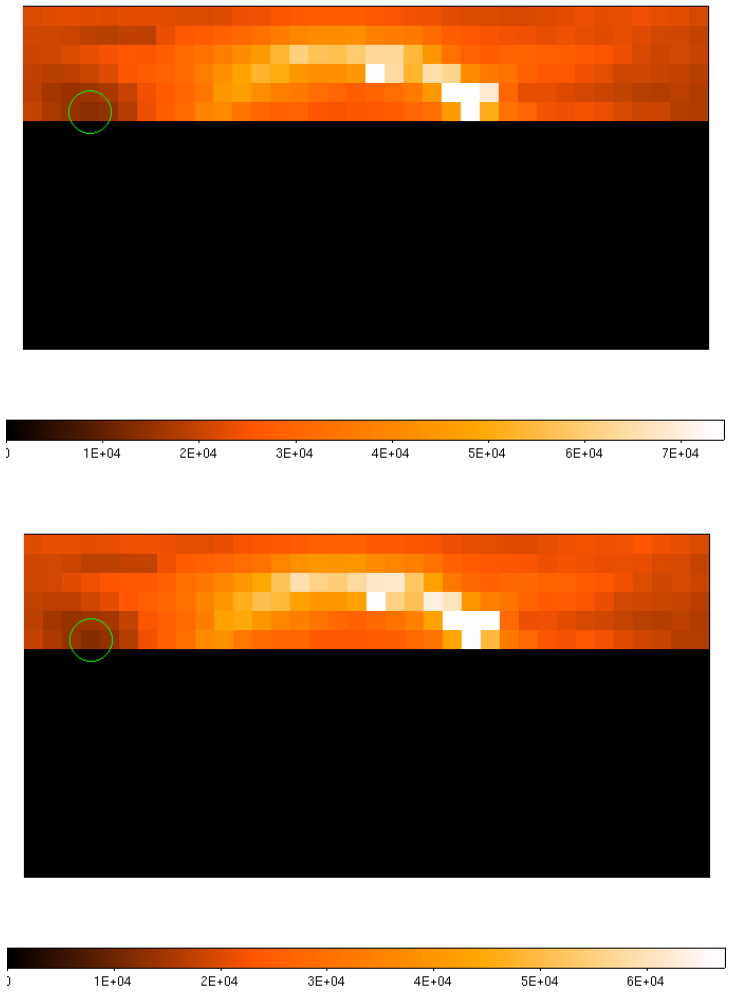


Figure: Brightness temperature distribution in coldest region pre- and post-subtraction

- $\frac{S_{tot} - S_{NVSS,408}}{S_{tot}} = 14.5\%$ for $S_{NVSS,408} \geq 6mJy$

Figure: Haslam 408 MHz map for $\delta \geq 30°$ pre- and post-subtraction, $10° \times 10°$ mean temperature regions



Comparison with ARCADE2

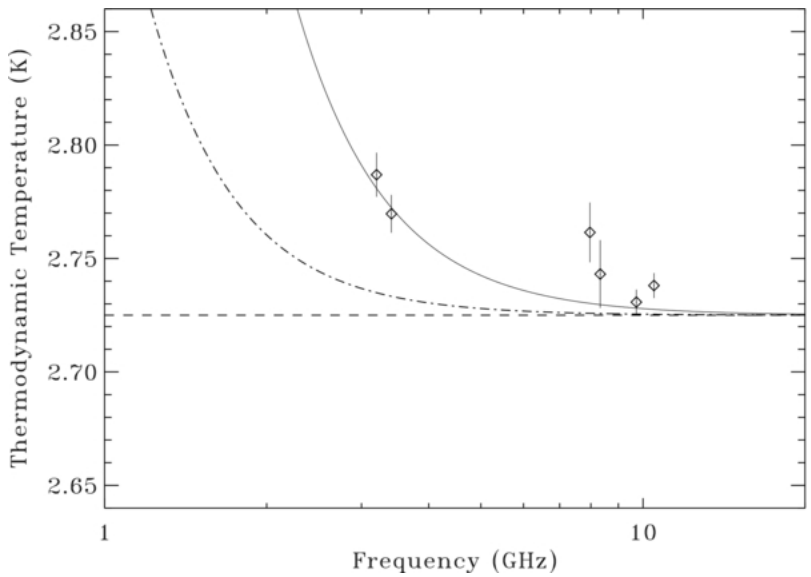
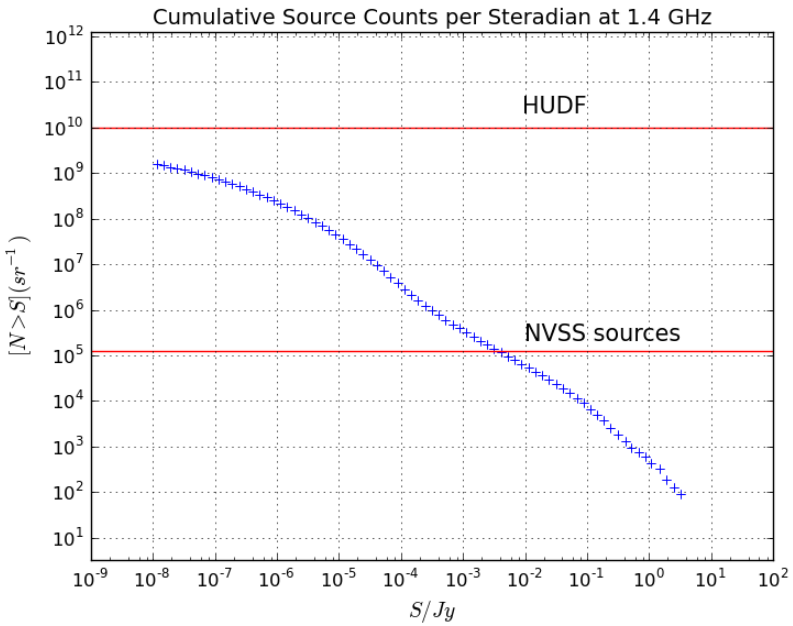


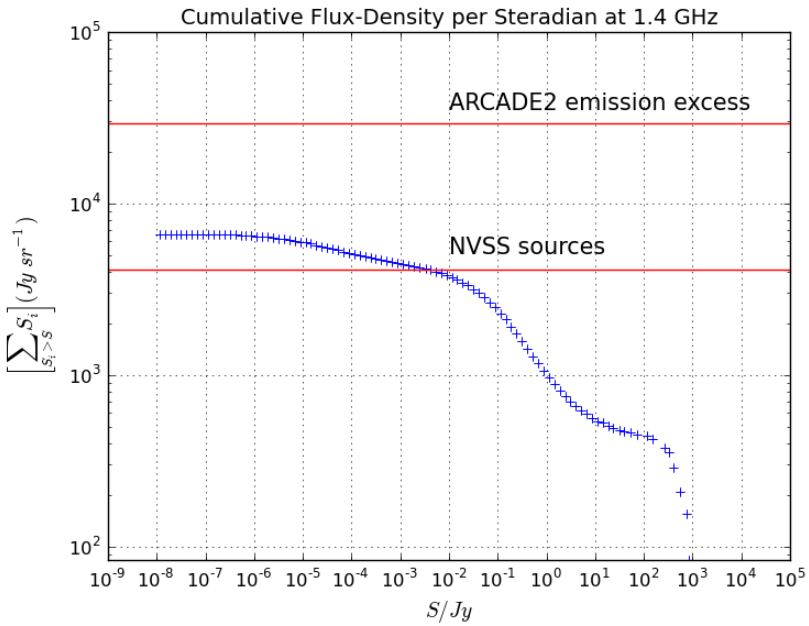
Figure: Detection of radio emission beyond the contribution of discrete radio sources, modelled galactic foregrounds, and the CMB. (Seiffert et al. [2011])

- Contribution of extragalactic sources to the excess emission: $(S_{1.4} > S_0 \simeq 1mJy)$ of $\sim 16\%$
- cf. coldest region $S_{NVSS,1.4} > S_0 = 3.4$ mJy comprises $\geq 14.5\%$ of extragalactic emission

Modelling Extragalactic Source Populations Below the Imaging Limit- S^3-SEX

- SKA Simulated Skies (S^3) - Simulation of EXtragalactic radio continuum sources (S^3-SEX) [Wilman et al., 2008]
- Additional modelled contribution increases the integrated total intensity contribution from extragalactic sources by 60% to 3.1 K





Galaxy Modelling

- After subtraction of the CMB and catalogued and modelled extragalactic source populations from the Haslam map, a 7.9 K remainder in the coldest region and ∼12 K at high Galactic latitudes is present
- ARCADE2 Galactic model derives it's normalisation from a plane-parallel model of Galactic structure:
  $T_B(\nu) = c(\nu) + T_G(\nu) \csc |b|$

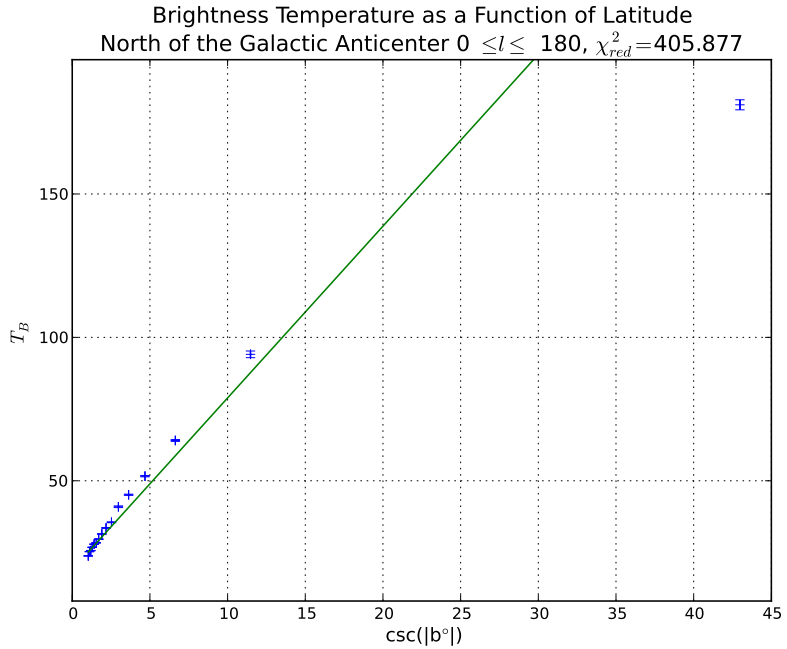
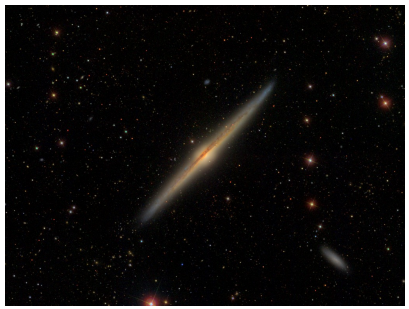
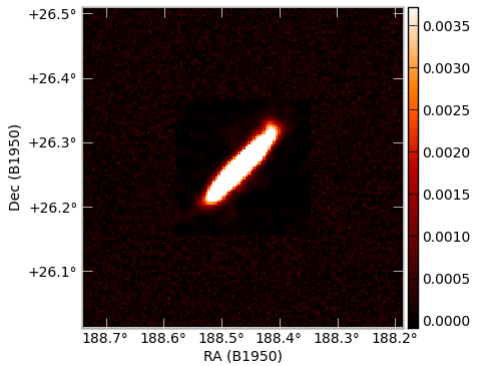


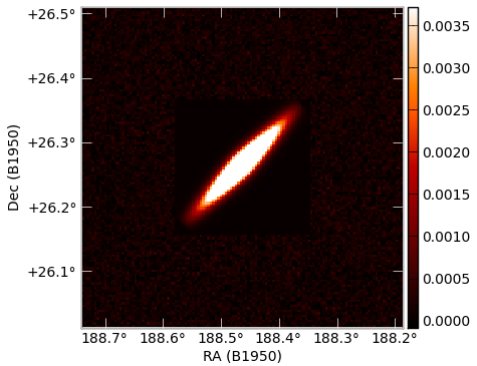
Figure: The least-χ^2 fit of a plane-parallel model to the Galaxy has reduced-χ^2 of 405 implying the model is insufficient to describe the structure present in the data

Galaxy Modelling

- Inherent difficulty in determining the level of high-latitude Galactic emission due to our position embedded within the disk
- Instead model nearby spiral galaxies to determine where in the distribution (i.e. how extreme) the Milky Way would have to be in order for the Galaxy to account for the missing ARCADE2 emission
- Emissivity model based on an isothermal thick and thin disk in hydrostatic equilibrium combined with energy equipartition







Galaxy Modelling

- Model 40 nearby spiral galaxies then rotate the maximum likelihood fits to face-on orientation
- At 408 MHz absorption is negligible so the Earth-equivalent intensity at high Galactic latitudes (looking out of the plane of the Galaxy), in an external modelled galaxy, will be half the face on intensity at a position 8 kpc from the galactic center

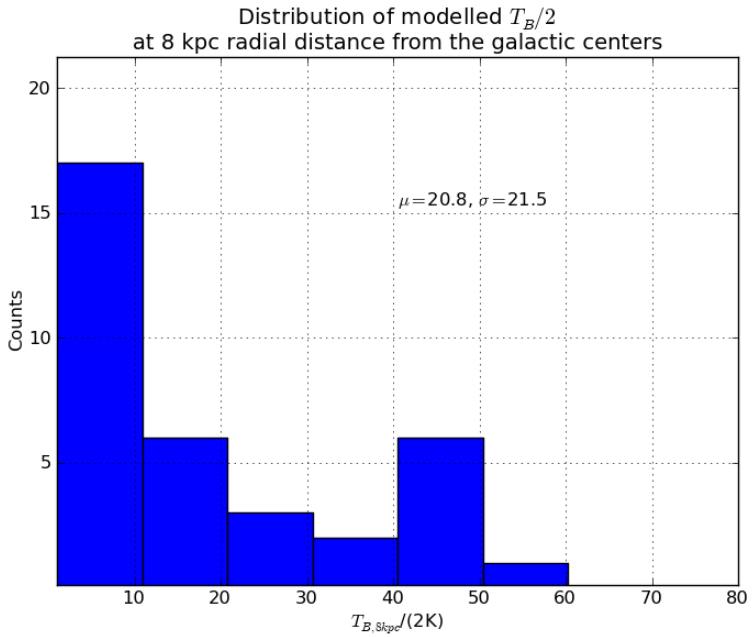


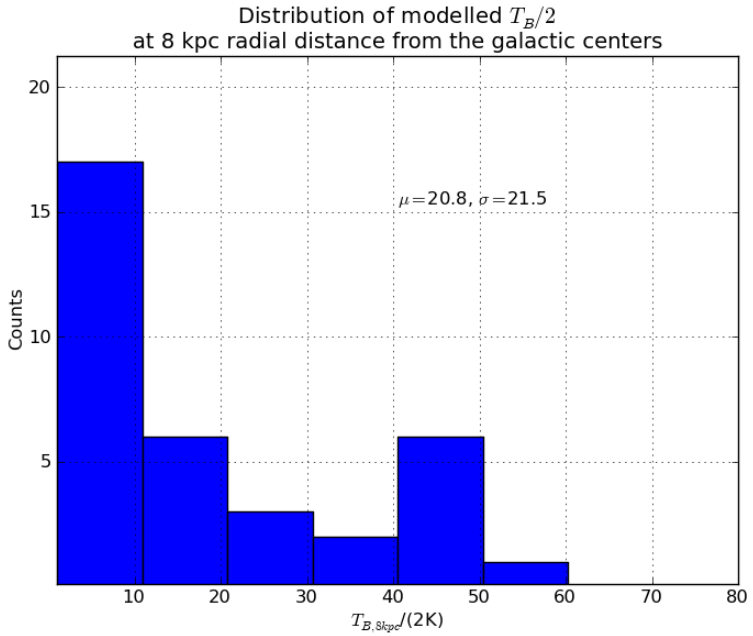
Figure: Histogram of 408 MHz half-brightness temperatures of modelled galaxies at 8 kpc radial distance from their centers

Galaxy Modelling

- Modelled emissivity decays exponentially with radius
- Exponential distribution of modelled half-brightness temperatures reflects the uncertanties in the galactic distances used
- Mean fitted half-brightness temperature,

$$\frac{T_{B,8kpc}}{2} = 20.8 \text{ K}$$

cf. 7.9 K remainder in the coldest region and $\sim$ 12 K at high Galactic latitudes



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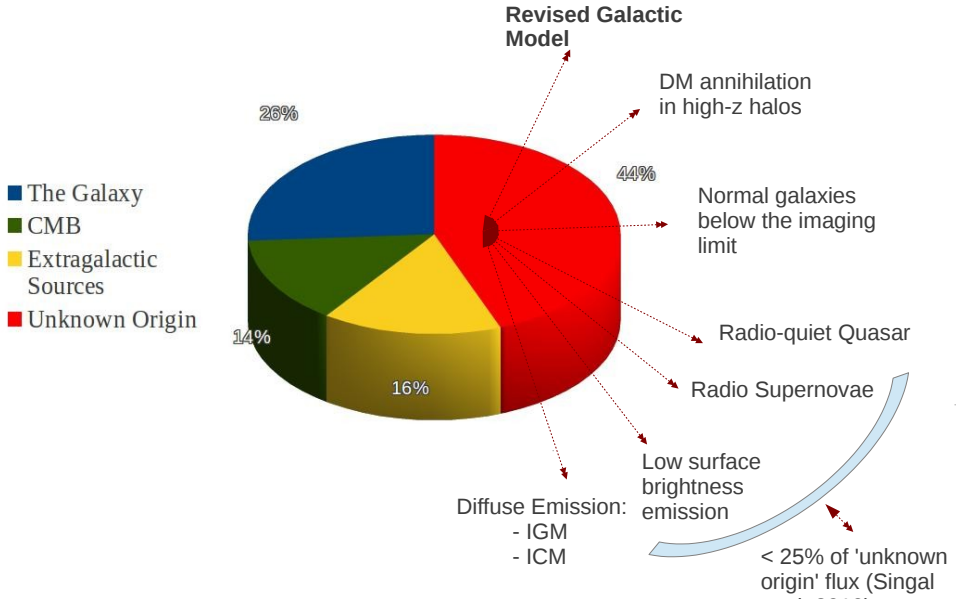
Summary & Conclusions

- Summary -
  - Total 408 MHz radio background at high Galactic latitudes: $T_{CRB} \approx 20$ K
  - Integrated extragalactic emission, catalogued (NVSS) + modelled (S^3-SEX) sources down to $S = 10^{-8}$ limiting flux-density: $T_{EGS} = 3.1$ K
  - 2.7 K CMB
  - **12 K high-latitude Galactic emission**



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