Extragalactic Radio Background from Synchrotron Emission of Radio and Normal Galaxies

Nomthendeleko Motha[1], Soebur Razzaque[1]

[1] *Center for Astro-Particle Physics (CAPP) and Department of Physics, University of Johannesburg, South Africa*

Abstract

The extragalactic radio background in the universe is mainly due to emission from the radio galaxies(RGs) and normal galaxies(NGs). This emission is synchrotron radiation by relativistic electrons gyrating in the magnetic field of the galaxies. Synchrotron self-absorption and free-free absorptions by hot ionised gas in the interstellar medium play an important role to modify radio emission. In this study, we calculate the radio spectra of the radio and normal galaxies. Thereafter, we develop a model for the intensity of extragalactic radio background by using the resulting radio spectra and integrating over the observed luminosity functions according to cosmological evolution. We compare our model with the latest radio source count data.

Introduction

The radiation from galaxies fills up the universe and is accumulated over cosmic time to form a background similar to the cosmic microwave background. The intensity of this background depends on different factors such as:

- the number of galaxies,
- the evolution of galaxies with cosmic time,
- the luminosity distribution of the galaxies,
- and in the case of normal galaxies, the radio-infrared correlation

The extragalactic radio background helps us to study the evolution of different types of galaxies observed at various radio frequencies, the star-formation rate in normal galaxies, the implications for ultra-high energy γ-ray propagation in the universe etc.

Conclusion

We established a new model for the extragalactic radio background using an updated [5] methodology:

- At low frequencies, the new estimate for the radio background surpasses the previous model by [5].
- Uncertainties presented by the new model were addressed by applying: (1) the recent model of the radio-infrared correlation [3], (2) the radio spectra of galaxies, (3) the evolved luminosity function consistent with observational source count data from [2].
- The new ERB displays an evolution cut-off between $z \sim 1-1.5$ for normal galaxies and $z \sim 0.5-1$ in the case of radio galaxies

References

[1] M. Aguilar et.al., Phys. Rev. Lett., 122 (2019), p. 101101.

[2] G. De Zotti et al., A&A Review, 18 (2010), pp. 1–65.

[3] T. Mauch and E. Sadler, MNRAS, 375 (2007), pp. 931–950.

[4] R. Protheroe, ApJ, 254 (1982), pp. 391–397.

[5] R. Protheroe and P. Biermann, Astropart. Physics, 6 (1996), pp. 45–54.

[6] Z. Yuan et al., ApJ, 846 (2017), p. 78.

The Synchrotron Spectra

In addition to the low energy cut-off in the cosmic ray spectrum (NGs: AMS Collaboration [1]; RGs: cut-off at 100 MeV [4]), synchrotron self-absorptions and free-free absorptions contribute to the low-frequency turn over observed in the radio spectra. See Figure 1.

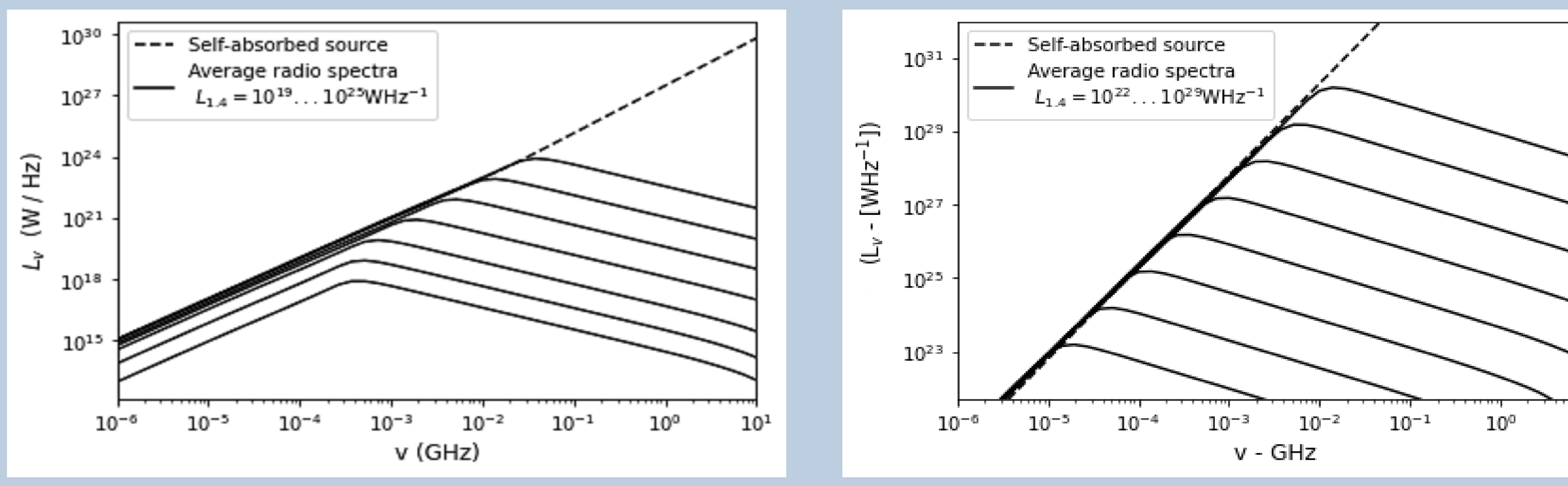

Figure 1. The average synchrotron radio spectra for (a) NGs with 1.4 GHz luminosity $L_{1.4} = 10^{19}...10^{25}$ W/Hz and (b) RGs with 1.4GHz luminosity $L_{1.4} = 10^{19}...10^{25}$ W/Hz W/Hz, including the effects of synchrotron self-absorption. The dashed line shows the maximum luminosity of a completely self-absorbed source.

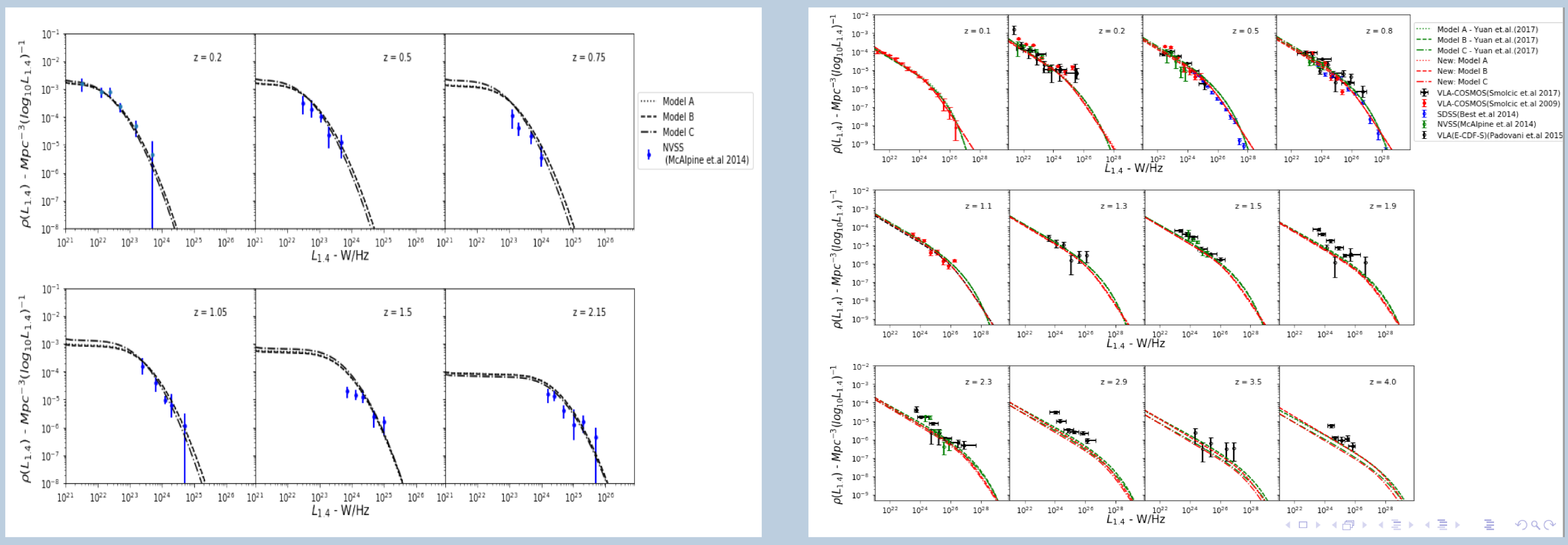

Figure 2. The RLF at 1.4 GHz using model A - C for (a) NGs at redshift z = 0.1,....,2.15. and (b) RGs at z = 0.1,...., 4.0 compared with data from various observational estimates.

- Using the updated source density evolution and luminosity evolution function proposed by [6], the radio luminosity at redshift z exhibits consistency with radio data from previous surveys: including the NVSS, FIRST, ELAIS and the PDS.
- Normal galaxies dominate the source count distribution at low frequencies below $\sim 10^{-3}$Jy

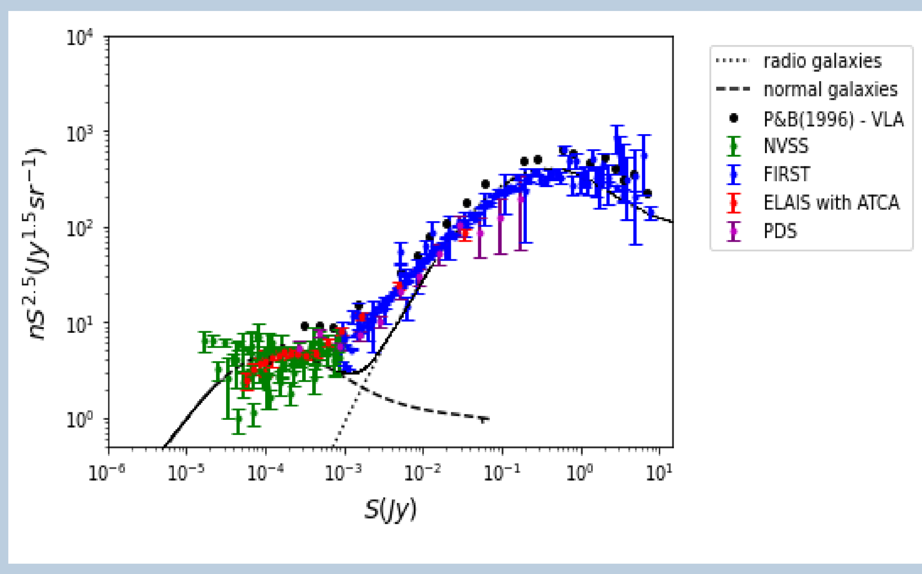

Figure 3. : The normalised radio source count distribution at 1.4 GHz for NGs and RGs compared with radio data. The solid curve represents the total source count density given by the sum of the dotted curve (radio galaxies [6]) and the dashed curve (normal galaxies).

The Updated ERB model

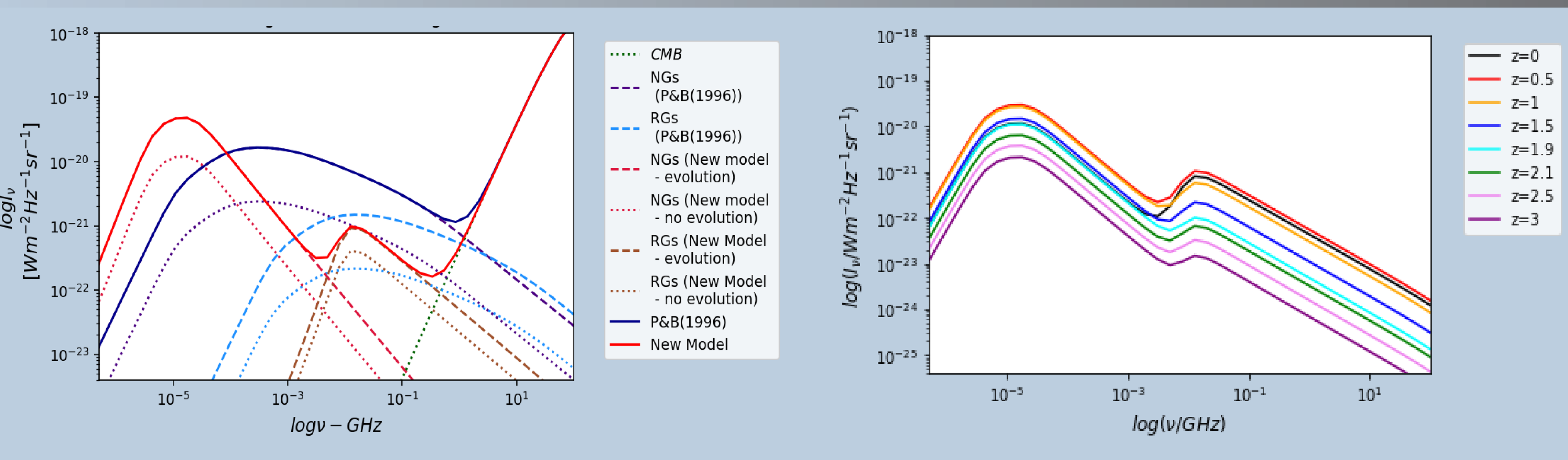

Figure 4.(a) The new extragalacitc radio background intensity (solid red curve) and the CMB (dotted green curve) compared to the [5] model (solid blue curve). Dashed lines: with source density evolution and luminosity evolution. Dotted lines: No evolution. (b) The extragalacitc radio background intensity at various redshift z.