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# Spectral index of synchrotron emission: insights from the diffuse and magnetised interstellar medium

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The interpretation of Galactic synchrotron observations is complicated by the degeneracy between the strength of the magnetic field perpendicular to the line of sight (LOS), $B_\perp$, and the cosmic-ray electron (CRe) spectrum. Depending on the observing frequency, an energy-independent spectral energy slope $s$ for the CRe spectrum is usually assumed: $s = -2$ at frequencies below ≃400 MHz and $s = -3$ at higher frequencies.
Motivated by the high angular and spectral resolution of current facilities such as the LOw Frequency ARray (LOFAR) and future telescopes such as the Square Kilometre Array (SKA), we aim to understand the consequences of taking into account the energy-dependent CRe spectral energy slope on the analysis of the spatial variations of the brightness temperature spectral index, $\beta$, and on the estimate of the average value of $B_\perp$ along the LOS.
We use 3D magnetohydrodynamic simulations of the diffuse, magnetised, multiphase, turbulent, and neutral atomic interstellar medium (ISM) as input for the magnetic field to study the variation of $\beta$ over a wide range of frequencies ($\simeq 0.1 - 10$ GHz).
We find that the common assumption of an energy-independent $s$ is only valid in special cases. We show that for typical magnetic field strengths of the diffuse ISM (≃2−20 $\mu$G), at frequencies of 0.1−10 GHz, the electrons that are mainly responsible for the synchrotron emission have energies in the range ≃100 MeV−50 GeV. This is the energy range where the spectral slope of CRe varies to the greatest extent. We also show that the polarisation fraction can be much smaller than the maximum value of $\simeq 70\%$ because the orientation of $\mathbf{B}_\perp$ varies across the beam of the telescope and along the LOS.
Finally, we present a look-up plot that can be used to estimate the average value of $B_\perp$ along the LOS from a set of values of $\beta$ measured at different frequencies, for a given CRe spectrum. This plot turns out to be particularly useful for SKA and a number of its pathfinders and precursors (HERA, MWA, MeerKAT, LOFAR, and ASKAP).

## Reasearch area

Magnetism

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