Preface

During the past decades, the observation of the diffuse radio emission from the Galaxy has regained attention. In the 1950s, the first full-sky radio surveys were done at frequencies between 100 and 400 MHz. These observations, albeit at low angular resolution of $\sim 20°$, revealed the basic Galactic structure and the presence of ‘spurs’ of emission. Some of the physics of the interstellar medium (ISM) was also revealed by these surveys. The nonthermal synchrotron emission coming from individual supernova remnants (SNRs) and also from the diffuse ISM provides information about the cosmic rays propagation and magnetic fields on the Galaxy. The brightness temperature and spectra of HII regions that are seen in absorption at low frequencies can be used to study the density and temperature of the gas in star forming regions.

More recently, observations of the Cosmic Microwave Background (CMB) have reactivated the interest in the diffuse radio sky. The CMB is observed in the frequency range between 10 and 300 GHz and within this range there is strong emission from our Galaxy, both diffuse and from compact objects. As the brightest point sources can be masked out in the CMB analysis, the diffuse emission presents the greatest problem for CMB cosmology and its understanding and removal is critical. The importance of this foreground emission analysis was recently demonstrated with the publicized announcement by the BICEP2 team. They had claimed the detection of the B-mode polarisation pattern in the CMB, which would have major implications for cosmology, since gravitational wave B-modes are expected to be produced during the inflationary process when the Universe was less than 10^{-32} s old. Observations by the *Planck* satellite later showed that the polarised signal that the BICEP2 team reported as cosmological B-modes, was produced instead by Galactic dust. The search for B-modes continues and a number of ground-based experiments are measuring the polarised sky with even greater precision than BICEP2 and *Planck*. Balloon-borne and satellite experiments are also planned for the near future, so the necessity for an accurate quantification of the polarised foreground emission at $\sim$100 GHz is essential.

Polarised emission between 20 and 300 GHz is thought to be produced by two main mechanisms, namely synchrotron radiation from relativistic cosmic rays spiralling around magnetic field lines, and thermal radiation from dust grains that are aligned coherently by a local magnetic field. These two emission mechanisms have different spectral behaviour. Synchrotron has, at first order, a steep power-law spectrum where the emission decreases with frequency so that this emission dominates at lower frequencies. Thermal dust on the other hand has a "modified black body" spectrum, which peaks at $\sim$3 THz, with a rising spectrum in the frequency range we are interested in. The frequency where these two emission mechanisms show similar intensity is $\approx$70 GHz, and therefore is the frequency where the minimum polarised foreground emission is observed. This would correspond to the ideal frequency to observe CMB polarisation. However, most CMB experiments today use higher frequencies, between 150 and 300 GHz. The reason for this is that CMB observations are designed to avoid synchrotron contamination. Dust emission can be accurately measured at higher frequencies and then used to subtract the emission at the CMB range. In the case of synchrotron emission this is not possible at the moment as we do not have a polarisation map at low frequencies with the required accuracy. Moreover, the synchrotron spectral index is not uniform over the sky, as we will see in this work.

In total intensity observations, the task of CMB foreground analysis is even more difficult. Besides synchrotron and thermal dust, there is also free–free emission from plasma nearby massive stars, and the relatively recently discovered anomalous microwave emission (AME). AME is a new emission mechanism at $\sim$30 GHz that is correlated with dust emission. It is thought to be originated by electric dipole emission from charged dust grains spinning at GHz frequencies. AME has been observed in many astrophysical environments and it is inherently diffuse. It is a major foreground contaminant for total intensity CMB observations. Until today, only upper limits of a few percentage points have been set up on its potential polarisation. Nevertheless, even if it is weakly polarized, it could complicate the CMB polarisation studies. AME is difficult to study due to its diffuse nature, being clearly detected by CMB experiments and telescopes at $\sim 1^\circ$ angular resolution but hard to detect at higher angular resolution when interferometric arrays are used. This presents a problem for identification of the emitters and its physical properties so, at the moment, we only know some general properties of AME, like being associated with photon-dominated regions (PDRs). On the other hand, detailed theoretical models have been constructed that predict the spinning dust spectrum for different grain types and astrophysical environments. They present an opportunity to study the ISM, in particular the smallest dust grains, from a new window at GHz frequencies. Spinning dust emission depends on factors such as hydrogen density, gas temperature and ionisation fraction, so the detailed comparison of the models with good observations will allow us to study the ISM conditions in a variety of environments.

This thesis encompasses these topics: the study of the ISM in its relationship with CMB observations, both in total intensity and polarisation. The so-called "CMB foregrounds" science involves a diversity of astrophysical topics, including magnetic fields, cosmic rays, plasma and dust grains physics. This makes it a complex and interesting field, which due to the precision required for CMB cosmology, allows us to understand in great detail the physics of the Galactic ISM.

The motivation of this work is to study some aspects of the microwave sky, both in polarisation and total intensity. First, we focus on the polarised synchrotron radiation as observed by *WMAP*. The sky emission is seen to be dominated by large-scale filamentary structures which have not been extensively described in the literature. We identified and catalogued them and study some observational properties, such as spectral indices, polarisation angles distribution and polarisation fractions. A second topic studied is the anomalous microwave emission from molecular clouds. In particular, we study the LDN 1780 cloud using ancillary radio and infrared data as well as interferometric observations at 30 GHz. The idea is to identify the AME emitters, which are thought to be small dust grains.

The rest of the thesis is organised as follows. In Chap. 2, the *WMAP* polarisation data is described, along with the further processing that we perform to the data. The polarisation amplitude *P*, being a definite positive quantity suffers noise bias. We describe the methods that exist to correct for this effect and present the corrected *WMAP* polarisation intensity maps that we use in the rest of this thesis. We also describe an application of the bias-correction technique to the quantification of the polarisation fraction of two AME dominated regions. In Chap. 3, we study the polarised diffuse emission using *WMAP* data. The work is focused on the characterisation of the polarised filamentary emission visible in the maps. The geometry of these features is studied as well as spectral indices and polarisation fractions. We also include an interpretation of the large-scale features and their possible connection to the local ISM. Chapter 4 is based on the Q/U Imaging Experiment (QUIET), a polarisation CMB experiment which observed regions of the sky at 43 and 95 GHz. We describe the instrument, observations and map-making process focused on the data from two regions observed on the Galactic plane. A comparison of the maps with *WMAP* data is shown and some basic analysis of the diffuse polarised emission on the Galactic regions. In Chap. 5 we use new interferometric data at 31 GHz to study the AME from the LDN 1780 cloud. The connection between the microwave emission and dust is studied using IR data that traces different dust grains. The parameter space of spinning dust models is explored and we compare with the observed physical conditions of the cloud. Chapter 6 summarises the main results of this work and also describes the future work.

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