The 2326 MHz Radio Continuum Emission of the Milky Way

A thesis submitted in fulfilment of the
requirements for the degree of

DOCTOR OF PHILOSOPHY

of

RHODES UNIVERSITY

by

JUSTIN LEONARD JONAS

October 1998

Abstract

The Rhodes/HartRAO *SKYMAP* survey is the highest frequency (2326 MHz) and highest resolution ($20'$) large-area pencil-beam survey of the celestial radio continuum emission. The survey covers 67% of the entire sky and is one of only two radio continuum surveys that cover the southern sky. These attributes make the survey eminently suitable for studying the extended radio continuum emission from the Milky Way. This thesis describes the methodology used to produce the *SKYMAP* survey map and presents an analysis of the galactic radio continuum emission.

Mountfort (1989) designed and implemented the original *SKYMAP* observing and data reduction procedures. These original procedures have been modified and extended to accommodate instrumentation upgrades at HartRAO and take advantage of new computer technologies that have become available. A new procedure was developed to perform the merging of the ten individual target-area maps into a self-consistent combined map without discontinuities at the component map boundaries. Calibration and data quality procedures were devised and implemented in order to validate the temperature scale and pointing accuracy of the map data. The uncertainty in the relative full-beam temperature scale is estimated to be 2% and the RMS pixel noise is less than $\Delta T_{\rm FB} = 30$ mK. The uncertainty in the zero-level of the survey map is conservatively estimated to be 80 mK. The RMS pointing accuracy is better than $1.9'$.

The diffuse galactic background (DGB) emission is shown to be consistent with four-arm spiral models for the Milky Way. The Gould Belt system and the galactic warp beyond the solar-circle are seen as non-symmetrical distortions in the DGB. An empirical model of the DGB was subtracted from the 2326 MHz map data in order to accentuate faint, extended radio sources.

A new technique was devised to discriminate between thermal and non-thermal radio continuum emission on the basis of FIR/radio flux ratios. This procedure was used to reduce the source confusion near the galactic plane.

42 new shell-like radio sources with angular diameters ranging from 1.6° to 26° are identified in the *SKYMAP* 2326 MHz map. These sources are probably large-diameter supernova remnants (SNRs) that partially redress the incompleteness in existing SNR catalogues caused by limited surface brightness selection effects. The shells of some of these faint, extended sources are incomplete towards high-latitudes. This morphology suggests that these objects are breaking out of the galactic disk and are releasing hot gas into the halo. There is no evidence for linear worm- and chimney-like features in the non-thermal galactic emission.

The spectral index of the diffuse galactic emission is calculated to be $\beta = 2.72 \pm 0.18$ between 408 MHz and 2326 MHz and $\beta = 2.95 \pm 0.08$ between 2326 MHz and 31 GHz, confirming previous work showing that the synchrotron spectrum steepens with increasing frequency. The high frequency spectral index is used to estimate upper limits on the galactic synchrotron foreground contamination of cosmic microwave background radiation measurements.

The high-latitude 2326 MHz galactic emission is shown to correlate weakly with the far-infrared galactic cirrus clouds. This correlation is due to thermal free-free radio emission from extended, low-density HII regions associated with the cirrus dust. The RMS level of this thermal signal is estimated to be 1 mK at 2326 MHz.

Two further experiments that need to be performed in order to complete the *SKYMAP* project are discussed: (a) the region of sky near the southern equatorial pole (SEP) needs to be mapped at HartRAO to complete the coverage of the entire southern sky, and (b) independent horn telescope (broad-beam) measurements of the sky temperature are required in order to reduce the baseline uncertainties in the current *SKYMAP* data.

Acknowledgements

The *SKYMAP* survey project would not have been possible without the dedication of Dr George Nicolson to the development of HartRAO as a radio observatory of international standing. His unfailing support of, and involvement in, the *SKYMAP* project was a major factor in its success.

Dr Peter Mountfort was responsible for the initial development of the *SKYMAP* observation and data reduction procedures. I owe him a huge debt of gratitude for providing me with a solid base from which to start my research career.

Without the encouragement and wisdom I have always received from my supervisor and mentor, Prof Eddie Baart, I would not have pursued a scientific vocation to this level.

My colleagues, both in the Department of Physics & Electronics and at HartRAO, have all contributed directly and indirectly to this project, for which I thank them. In particular I thank Prof Graham Poole for his meticulous proof-reading of a thesis outside of his research field.

The *SKYMAP* survey has been my major preoccupation since 1980, and the lives of my family have inevitably been drawn into the project. I thank Bev and my mother for their unlimited patience and support over this long and sometimes frustrating period.

During the course of this thesis I have received financial support from the Foundation for Research Development (FRD), the Rhodes University Council, the Max-Planck-Institut für Radioastronomie (MPIfR) and the International Astronomical Union (IAU).

I dedicate this thesis to the memory of my father who, although not trained as a scientist himself, taught me many of the essential experimental and practical skills that I have needed in my career as an empirical scientist.

Contents

List of Figures

List of Tables