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A 1·6 MHz Survey of the Galactic Background Radio Emission

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Abstract

Observations of the galactic radio emission at 1·6 MHz have been made during the current solar activity minimum using a radio telescope with a beamwidth of 25°. The radiation intensity was mapped for six declinations between −12° and −72° and from 1000 to 0500 hours R.A.

1. Introduction

During the last two solar minima, a series of low frequency ground-based observations of the galactic radio emission was made using three large filled-aperture radio telescopes, one of diameter 1100 m at 2·13 MHz (Reber 1967), one of area 1220×305 m^2 at 4·7 MHz (Ellis and Hamilton 1966), and a broadband telescope 585 m×585 m for the frequency range 2·5–18 MHz (Ellis 1972). Maps of the galactic radio distribution were produced for 2·13, 3·7, 4·7, 5·5, 8·3, 13 and 16·5 MHz with angular resolutions of a few degrees (Reber 1967; Ellis 1982). However, attempts to extend the observations down to 1 MHz proved unsuccessful owing to unsuitable ionospheric conditions (Reber, personal communication). These maps remain the only ones in existence for this frequency range and resolution. Their main feature is an absorption trough along the plane of the galaxy approximately 30° wide at 2·13 MHz. The attenuation of the radiation is probably caused by free–free absorption in the interstellar ionised hydrogen (Ellis 1982) and it increases rapidly with decreasing frequency. Below 2 MHz, it seems likely that the local region of the galaxy is the main source of the radiation.

During the present solar minimum, a new series of observations below 2 MHz has been made and, as it proved, ionospheric conditions were more suitable than at any time since the minimum of 1954. In addition, as part of the Spacelab-2 experiments of the Space Shuttle Challenger, an ionospheric hole was created over the telescope to facilitate some of the low frequency observations (Ellis *et al.* 1987; Mendillo *et al.* 1987).

2. Observations

The radio telescope used was a horizontal array of eight 180 m broadband dipoles with overall dimensions 330×400 m^2, 12 m above ground and located near Hobart, Tasmania (Lat. 42·9 S, Long. 147 E). It had a beamwidth of 25° at 1·6 MHz at the zenith, an operating frequency range of 1·00–2·75 MHz, and was used as a transit

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instrument with six simultaneous beams spaced in declination. The signals were recorded with six receivers, the frequency of each being swept through 12 kHz five times per second to locate clear channels between frequencies occupied by transmitting stations. The galactic noise power between stations was recorded with a minimum detector. Ceramic intermediate frequency filters with a bandwidth of 5 kHz were used in each receiver channel.

Calibration of the overall sensitivity of the receivers was carried out using noise generators in each of the antenna input channels. For calibration of the whole system, including the antenna, the intensity of the recorded galactic background radiation was compared with that obtained from low angular resolution observations in the direction of the South galactic pole using the lunar orbiting spacecraft RAE2 (Novaco and Brown 1978). A six channel recorder with a response time of 1 ms was used to record the signals.

Observations were made from May to August 1985 and from April to July 1986. The observations associated with the Spacelab-2 experiment were made on 5 August 1985. The ionospheric critical frequency foF2 was sufficiently low (less than about 1·3 MHz) and the level of interference from broadcast transmitters small enough to allow satisfactory observations at 1·6 MHz on only five nights in 1985 and six in 1986. Nevertheless, enough records were accumulated to allow the galactic radio distribution to be mapped between declinations $-12°$ and $-72°$ and from 1000 to 0300 hours R.A. at 1·6 MHz. For the region from 0300 to 0500 hours R.A., data from the Spacelab-2 experiment were used. In analysing the data, records were chosen which as far as possible included observations for directions near the galactic pole and hence could be calibrated. For each declination, the best records were chosen for smoothness of trace, reproducibility and absence of transmitter station interference, and the average intensity versus right ascension was calculated. No correction for ionospheric absorption was made since previous analyses have shown that, under the conditions of low ionospheric critical frequency in which the observations were made, the total ionospheric attenuation would have been expected to be less than 0·5 db. Fig. 1 shows the variation of the background radiation with galactic coordinates at 1·6 MHz.

3. Discussion

The 1·6 MHz map is basically similar to the 2·1 MHz map, but with an absorption trough approximately 40° wide along the plane of the galaxy, rather than the 30° width observed at the higher frequency. It should be noted that the original 2·1 MHz map showed large scale galactic absorption structure normal to the Earth's axis (Reber 1967). A re-examination of the original observations (Reber, personal communication) led to a map similar to the 1·6 MHz map described here (Ellis 1982).

The increase in the width of the trough between 2·1 and 1·6 MHz is consistent with the simple model of absorption by interstellar free electrons along the plane of the galaxy derived from high resolution observations at 16·5, 13, 8·3, 5·5, 4·7 and 2·1 MHz (Ellis 1982). At lower frequencies, the effect of the plasma on the synchrotron emissivity would be expected to lead to a more anisotropic distribution of the radiation (Ramaty 1972).

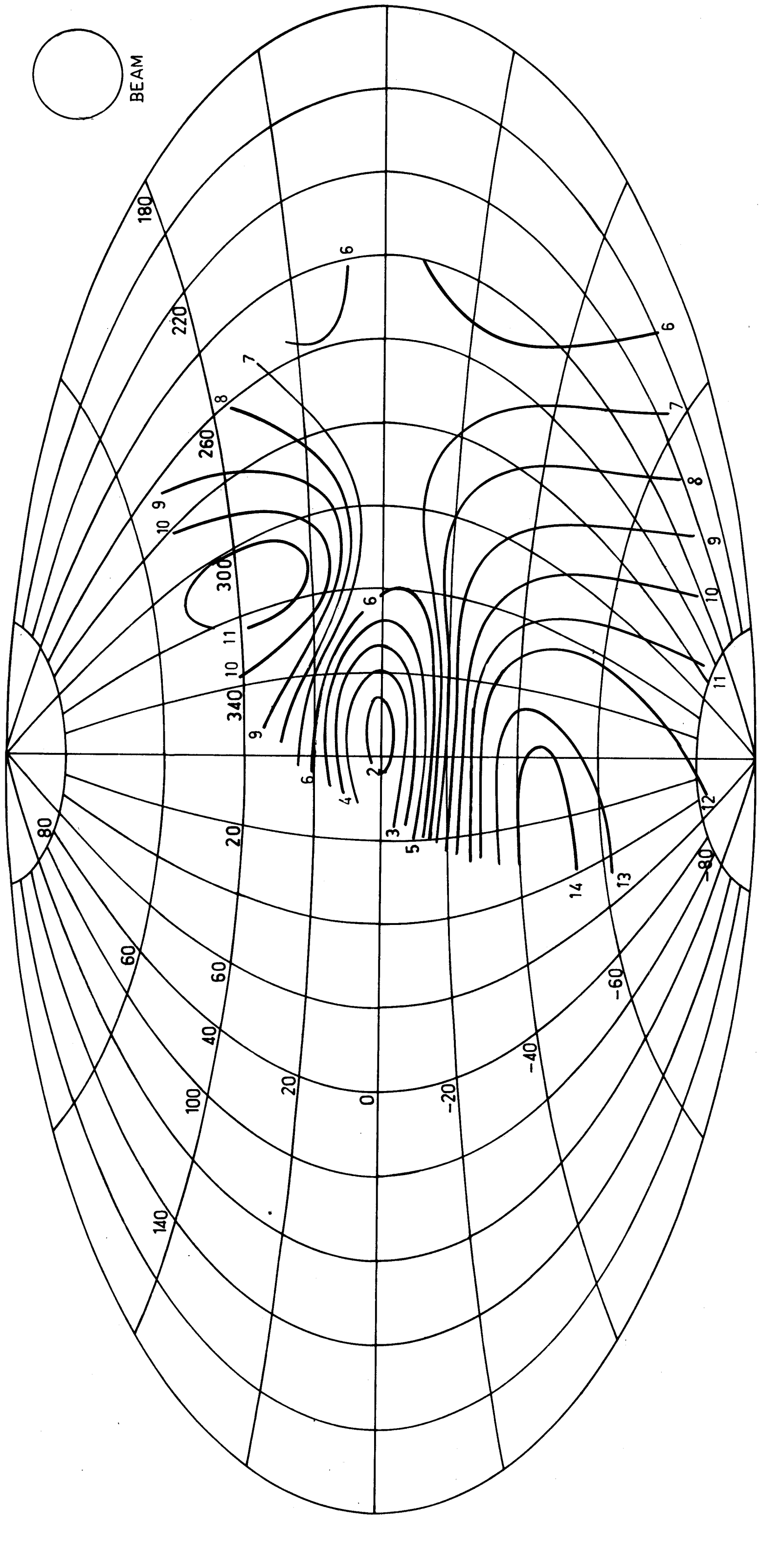

Fig. 1. Contours of brightness temperature ($\times 10^6$ K) at 1·6 MHz.

4. Conclusions

The 1·6 MHz observations have provided the first measurements of the distribution of the galactic radiation with 25° angular resolution. They show a broad absorption feature along the galactic plane generally consistent with that expected from observations at higher frequencies. A detailed theoretical analysis of appropriate galactic models needed to account for the observations will be given in another paper.

Acknowledgments

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Guest Comment

In June 1986, 36 astrophysicists from two countries, Australia and the Soviet Union, gathered at the Radioastronomical station of the P. N. Lebedev Physical Institute in the small town of Pushchino, outside of Moscow, to discuss their respective work on supernova remnants and pulsars and to plan cooperative projects. This symposium was dedicated to the memory of the Soviet astrophysicist Iosif Samuilovich Shklovskii (1916–85) in appreciation of his long interest in supernovae and their remnants.

Shklovskii a world-renowned theoretical astrophysicist was born in the Ukraine in 1916 and graduated from Moscow University in 1938 where he became a professor and remained until 1953. He was head of the Department of Radio Astronomy at the Sternberg Institute until 1972 and then director of astrophysics at the Institute of Space Research in Moscow until his death in 1985.

We remember him best for his work on nonthermal radio emission from the Milky Way, radio galaxies and supernova remnants. His proposal in 1953 that the radio emission, and indeed the continuum optical emission, from the Crab Nebula was synchrotron and hence polarised, was vindicated by later observations and firmly established the synchrotron process as the dominant source of radio emission from supernova remnants and radio galaxies. From this work he laid the foundations for evolutionary models for supernova remnants.

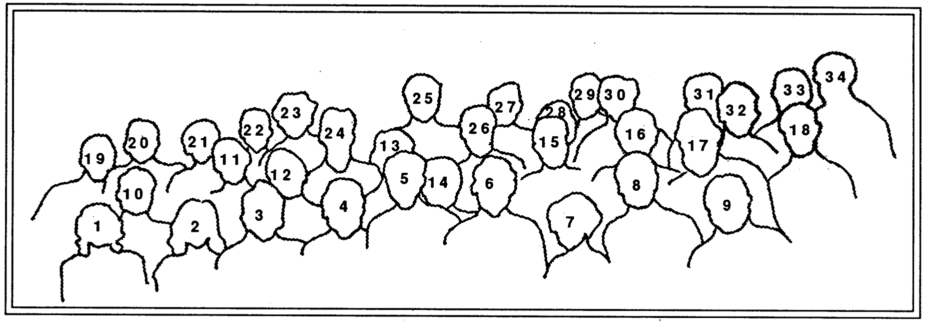
Apart from his work on supernovae and radio galaxies, Shklovskii originated the currently accepted ionisation theory for the solar corona. He calculated line strengths and wavelengths for molecular lines and predicted their discovery. He suggested a new way to estimate the distance to planetary nebulae and contributed to the interpretation of X-ray and pulsar emission.

Shklovskii was the author of seven books and about 200 scientific papers. He was a member of the Academy of Sciences of the USSR, the Royal Astronomical Society, the American Academy of Sciences and Arts, the US National Academy of Sciences and the Canadian Astronomical Society, and was a Bruce medallist of the Astronomical Society of the Pacific.

At the Pushchino meeting 30 papers were presented, and most are published here, covering the origin, spatial distribution, structure, classification and evolution of supernova remnants (SNRs) and pulsars. A study of these objects, the last stages of stellar evolution, can tell us much about the creation of the elements, the interaction of relativistic plasma and magnetic fields, and the behaviour of extremely dense matter and high magnetic and electric fields.

There was a fair division of interest between supernova remnants and pulsars and between observation and theory and it was beneficial to see in what direction research is moving in the two countries, each with a long history of supernova research. Not included in this issue are the very interesting discussions by G. S. Bisnovatii-Kogan on the 'Evolution of Binary Systems and the Origin of Pulsars' which asks why there are not many more binary pulsars, and by A. D. Kuzmin, V. M. Malofeev, V. A. Izvekova, W. Sieber and R. Wielebinski

Participants in the Joint USSR–Australia Shklovskii Memorial Symposium on Supernova Remnants and Pulsars



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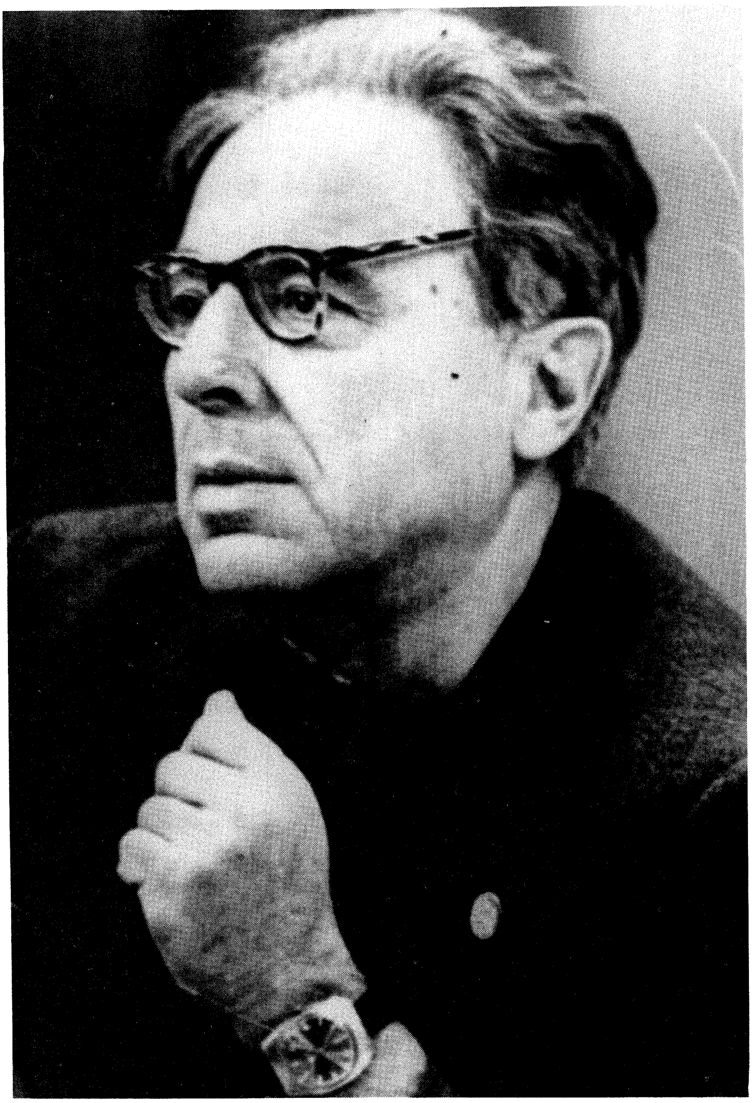

I. S. Shklovskii (1916–85)

whose observations of pulsar pulse profiles has led them to a 'Two-component Magnetic Field Model'. A. V. Tutukov and L. R. Yungelson summarised their work on 'The Stages of Stellar Evolution Immediately Preceding the Supernova'. A. R. Turtle reported on the work at the Molonglo Observatory on Magellanic Cloud supernova remnants and R. N. Manchester reported on the Molonglo search for millisecond pulsars. All of these papers have been published elsewhere.

The large organisational task was performed by the two joint chairmen of the scientific organising committee, Professor A. D. Kuzmin of the P. N. Lebedev Physical Institute and Dr R. N. Manchester of the CSIRO Division of Radiophysics. It was largely through their efforts that this meeting was held. We also express our gratitude to the *Australian Journal of Physics* and in particular its editor Mr R. P. Robertson for making it possible to publish these proceedings.

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