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THE DISTRIBUTION MODELS OF THERMAL AND NON-THERMAL RADIO CONTINUUM EMISSION IN THE GALACTIC DISK

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ABSTRACT

In the past, it was very difficult to distinguish thermal and non-thermal emission. Broadbent et al. (1989) has developed a new technique with the help of the IRAS 60 micron emission. The distribution of non-thermal or synchrotron emission in the Galactic disk has been modeled from the 408 MHz all sky survey of Haslam et al. (1982) after removal of the thermal component. At 408 MHz, there is very little absorption in the interstellar medium and the distribution along the line-of-sight is inferred mainly from its presumed relationship to other tracers of spiral structure via a number of fitted parameters. But at lower frequencies, free-free absorption becomes important and can give some direct information on the line of sight distribution. We have modeled the thermal electron density according to the spiral arm models and the distribution of ionized hydrogen in the Galactic plane by Lockman (1976) and Cersosimo et al. (1989) and have made predictions to compare with the surveys of Dwarakanath et al. (1990) at 34.5 MHz and Jones and Finlay (1974) at 29.9 MHz. The result confirms that the absorption model of the synchrotron emissivity in the Galactic plane is broadly corrected and illustrates the potential of the absorption technique.

I. INTRODUCTION

The radio emissivity of the Galaxy gives information about the distribution of magnetic field and cosmic ray electrons. However, there is a problem of distinguishing the thermal and the non-thermal components of the radio continuum emission. For Galactic latitudes , the emission is essentially all non-thermal(synchrotron) . At lower latitudes, there is a thermal component from the bremstrahlung of thermal electrons in compact and extended HII regions. Having developed a technique for the separation of the thermal and non-thermal components based on the strong correlation of the former with 60 micron infrared emission after subtraction HI-associated dust component, we were able to deduce a more detailed of spiral arm structure closed to the Galactic plane.

The 408 MHz allsky survey of Haslam et al.(1982)has enabled us to deduce models of the distribution of synchrotron emissivity. For the 408 MHz , there is very little absorption in the interstellar medium and no direct information on the line of sight distribution of synchrotron emissivity. At lower frequencies, the free-free absorption becomes important and we use this to obtain direct information on the line of sight distribution and some indication of the relative positions of the peaks of synchrotron radiation that are related to cosmic ray electron density and magnetic field and ionized hydrogen emission within spiral arms related to regions of star formation and possible cosmic ray origin.

II. NON-THERMAL EMISSION MODEL

We have revised the spiral structure in the inner part of the Galaxy of Broadbent et al.(1989) by including a bar at the centre according to the evidence given by Blitz et al.(1993). We do not attempt to model the bar itself because of its orientation that falls almost entirely in the region where the thermal-nonthermal separation technique cannot be applied, and we have no clear prediction of the orientation and regularity of the magnetic field of the bar. However, the bar does have implications for geometry of the spiral arms as they approach the Galactic centre and this was taken into account. The spiral structure is shown in Fig. 1. We have also adjusted the inner arms for fitting the prediction with the observed profiles of non-thermal emission along the Galactic plane. The model is defined by the expressions and parameters given in Table 1. One should make clear that as this is based on a radio survey which has HPBW 51' it can represent detail down only to a scale size of typically 130 pc. This is roughly the thickness of the molecular gas layer in the inner Galaxy but is considerably small than the deduced thickness of the synchrotron emitting disk. The fitted profiles between the observation after removing the thermal component and the prediction are shown in Fig. 2.

III. THERMAL ABSORPTION MODEL

At 408 MHz , there is very little absorption in the interstellar medium. In contrast at frequencies (30 MHz. the absorption of synchrotron emission due to thermal electrons becomes significant. The optical depth of thermal plasma, with a mean square electron density for free-free absorption at frequency (Te is the electron temperature(a typical value is 7000 K). At low frequencies, the HII regions act as absorbers of the background synchrotron emission. As there is recombination line emission as sociated with the thermal continuum, its distribution along the line of sight can be obtained from our spiral arm model and an alternative model based on pulsar dispersion measures together with the Galactic rotation curve(Clemens, 1985). We have then applied our synchrotron(non-thermal) model at lower frequencies including the absorption to compared with the surveys of Dwarakanath et al.(1990) at 34.5 MHz and Jones and Finlay(1974) at 29.9 MHz. Our resulting distribution of thermal electrons is shown in Fig. 3 and Fig. 4 shows the observed transmission and those predicted for two HII distributions.

IV. CONCLUSION

It might be argued that the number of parameters that we have introduced into our model is larger than necessary but we do believe that all the parameters that make up our model are there for a good reason concerned with the physics of the synchrotron emission and the spiral structure and that they have to be included in any realistic model. We also modeled the absorption of the continuum emission at decametre wavelengths by using the distribution of ionized gas and compared it with observation. The aim was to test the line of sight distribution of synchrotron emission in our model and to distinguish between two variants of the distribution of mean square thermal electrons density. The result confirmed that the absorption model of the synchrotron emissivity in the Galactic plane was broadly corrected. However, we were unable to distinguish between the two spiral arm distributions of thermal electrons, for which the main differences were in the form of the arms within 4 kpc of the Galactic centre. The reasons for this were that the available recombination line surveys did not really have sufficient frequency resolution and the inherent distance ambiguity when converting Doppler shifted frequency to the distance along the line of sight. At almost all longitudes the 'observed' transmission of decametre emission did fall between the predicted limits, corresponding to the assumption that all of the ionized gas was either at the near or far points. In certain directions one may be able to resolve this distance ambiguity. If one was completely confident of the model and the observed transmission, one could turn the problem around and for each longitude assign the ionized gas between the near and far points in the proportion required to give agreement with observation. This would then give a way of deriving the distribution of ionized gas in the Galaxy without the distance ambiguity.

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