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The large scale structure of the galactic center at low radio frequencies

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Abstract. A region about 10° around the galactic center (G.C.) has been studied in surveys available between 19.7 and 408 MHz. The maps show a trough near the G.C. sided by two intense emission peaks. Interpreting the observations as produced by an HII region that absorbs the radiation from bright non-thermal sources we propose a model consisting of four sources concentric with the G.C. and embedded in a diffused non-thermal background. Two sources, the $broad$ and the $narrow$, are non-thermal and we determine their temperature spectrum (indices -2.7 and -2.4, respectively), the third source is an HII region for which we compute the emission measure, and the fourth source is Sgr A complex. The broad source is prominently seen below 408 MHz while the presence of the narrow source is reported here for the first time.

Key words: Galaxy: center – Galaxy: structure – Radio continuum: general

1. Introduction

The University of Chile has just finished a 45-MHz sky survey, covering from the south pole up to δ = +19.1°, with a transit array having an angular resolution of 4.6°(α) x 2.4°(δ) (Alvarez et al. 1997). In the course of this work we noticed that the point with the highest brightness temperature in the region around the galactic center is not at the position l = 0°, b = 0°, as expected from higher frequency surveys, but it is at l = 2.1°, b = 0.1°. This apparent shift of the brightest point led us to examine the large scale structure of a region about 10° x 10° centered at the G.C., in maps made at frequencies equal or lower than 408 MHz. These surveys are listed in Table 1.

In what follows we will designate a point at galactic coordinates $l = l_0$, $b = b_0$ as (l_0, b_0). The maps at 85.7, 34.5, 30.9, 29.9 and 19.7 MHz show a trough near (0°, 0°), first noticed by Mills (1956) who saw "an extended bright emission region [that] stretches along the galactic plane for about 5° or 6° with two maxima about 2° apart, more or less symmetrically situated with regard to the centroid of the object, which is practically coincident with the source NRL5". This source had been suggested as the galactic nucleus by Haddock et al. (1955). Mills further suggested that such a structure could be "explained in terms of an HII region in front, or partly in front, of an elongated non-thermal source. With an electron temperature of about 10000 K, the HII region would appear in absorption against the much brighter background radiation, producing maxima in emission on either side, similar to those observed". Although Mills observations have been mentioned by several authors, e.g. Cooper & Price (1964), Burke (1965), Little (1974), they have not been further investigated. The purpose of this paper is to test some of these ideas with new observations at other frequencies.

In a first approximation we have tried a preliminary model whose failure suggested a more elaborate one which is analyzed in this work.

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2. The data

Some of the observations listed in Table 1 are of limited use for our purpose because: a) high resolution observations have been obtained with aperture synthesis, loosing the low spatial frequencies and preventing the study of large or medium scale structure; b) the 29.9-MHz map by Jones & Finlay (1974) is a composite of original synthesis observations to which the galactic background at 30 MHz, taken from Mathewson et al. (1965), was added. The method used to combine the maps is based on several assumptions and it is subjected to errors; c) The 85 and 150-MHz data from Wielebinski et al. (1968), correspond to background surveys from which point sources were removed (Wielebinski, private communication), so possible peaks in the center area may have been lost; finally, d) the 19.7-MHz data from Shain et al. (1961) suffer from severe and widespread absorption. Because of these limitations, and except for restricted use of the 29.9 and 30-MHz data, our analysis has been based only on the surveys at 45, 85.7 and 408 MHz.

The two maxima noticed by Mills near the G.C. at 85.7 MHz (Mills 1956, Fig. 1) are centered approximately at galactic coordinates (−0.7°, −0.3°) and (1.2°, 0.0°), and we will define

Table 1. Low-frequency surveys covering the galactic center area

ν (MHz)	Angular resolution (α x δ)	Instrument	Reference
408	0.8°	dish	Haslam et al. (1982)
408	2.9′ x 2.9′ sec$z$	cross	Green (1974)
150	2.2°	dish	Wielebinski et al. (1968)
85	3.7°	dish	Wielebinski et al. (1968)
85.7	50′	cross	Hill et al. (1958)
45	4.6° x 2.4°	filled array	Alvarez et al. (1997)
34.5	26′ x 42′ sec($\delta - 14.1°$)	synthesis	Dwarakanath & Udaya Shankar (1990)
30.9	13′ x 11.1′	synthesis	Kassim (1980)
30	11°	dish	Mathewson et al. (1965)
29.9	0.8° x 0.8° sec($\delta - 33.86°$)	synthesis	Jones & Finlay (1974)
19.7	1.4° x 1.4°	cross	Shain et al. (1961)

them as the western and eastern peaks, respectively. These peaks are seen in the survey at the same frequency made by Hill et al. (1958), and they appear as well at 29.9 MHz (Jones & Finlay 1974, Fig. 2f). At 45 MHz the eastern peak, at (2.1°, 0.1°), is dominant while the western peak, at about (−1.5°, 0.5°), is not completely resolved (Alvarez et al. 1997). The maxima are clearly seen also in the 34.5 and 19.7-MHz maps, however in the 30-MHz survey they are washed out because of its low resolution (11°). The 30.9-MHz synthesis map has too high a resolution (13.0′ x 11.1′) and shows abundant small scale structure so the two peaks are not recognizable. The 408-MHz map by Haslam et al. (1982) shows a single peak centered at (0°, 0°), while in the high resolution map by Green (1974), at the same frequency, there is no indication of any of the peaks. From this description we may conclude that the two maxima begin to appear somewhere between 408 and 85 MHz. Between the peaks there is a trough which is clearly seen at 85.7, 34.5, 30.9, 29.9 and 19.7 MHz. The position and the estimated uncertainties of these three features at different frequencies are shown in Table 2.

The position of the trough is not very sensitive to frequency and at 45 MHz it is more uncertain because of beam smoothing. The eastern peak is somewhat more sensitive to frequency, specially in longitude, while the western peak shows large changes in both coordinates, specially in latitude. The last column of Table 2 shows also the angular distance between the centers of the peaks.

3. Analysis of the models

Following the model suggested by Mills (1956) we have assumed that the trough is produced by the absorption of an HII region in front of, or immersed in, a broad and bright source which appears as two maxima. To analyze the double peaked structure we have studied temperature profiles taken along the line connecting the peaks, and also along the equator. Dish and filled-array observations show along the equator a broad and strong feature several degrees wide superposed on a smooth and intense background that tapers off with distance from the center (Fig. 1). To determine this background, that will be a part of our models, we filter out the high spatial frequency components from the temperature profile using the method of Sofue & Reich (1979), somewhat modified. The profile along the line connecting the peaks, which at 45 MHz and below runs slightly inclined to the equator, shows the two peaks and the trough in between them. In an attempt to retrieve the magnitude of the absorbed source we fit a gaussian curve to the wings of the profile, that is, to the part not absorbed. We have defined this gaussian as the $expected\ profile$, the nomenclature for which is illustrated schematically in Fig. 2. The corresponding gaussian fits are shown in Fig. 3. Table 3 presents the measured parameters as defined in Fig. 2 and the angular size represented by the FWHM corrected for beam smoothing assuming a gaussian beam. The absorption depth Δ at 45 and 85.7 MHz is 4 σ and 10 σ, respectively, being σ the rms dispersion of the fits. We found that the temperature of the base of the gaussian fit, $T_{\rm B}$, and that of the diffuse background, which should be the same, differ by less than 10%, and this has been considered satisfactory. For the 408-MHz profile, at b = 0°, a good fit was obtained with two gaussians rather than one, so we have associated the wide gaussian (FWHM = 3.1°) with the source we will define as the $broad$ source while we have associated the narrow gaussian (FWHM = 0.8°) with an emission that replaces the absorption dip (Δ = −1100 K). In the case of the 408-MHz profile T_o corresponds to the peak temperature.

3.1. Preliminary model

There is evidence for the existence of an HII region in the direction of the galactic center. Jones & Finlay (1974) studying discrete absorption regions at 29.9 MHz along the galactic plane, found only one such a region within +6.3° and −4.4° from the G.C. Its location at (−0.4°, +0.1°) coincides fairly well with the position of the trough, as shown in Table 2, therefore we assume that it is the object that causes the trough. The size of the region was estimated as 1.5° x 1.0° (Jones & Finlay 1974), which is the value we will adopt to compute later the subtended solid angle. Also, Downes & Maxwell (1966) observing the galactic center region at 3 GHz found an extended thermal source, or congregation of unresolved sources, covering l = ±0.5°, b = ±0.2°. To

Table 2. Positions of peaks and trough near the galactic center

Frequency (MHz)	Trough (l°, b°)	Eastern peak (l°, b°)	Western peak (l°, b°)	Distance between peaks (°)
85.7	(−0.1, −0.1)±0.3	(1.2, 0.0)±0.1	(−0.7, −0.3)±0.1	2.0
34.5	(−0.4, +0.2)±0.1	(2.1, −0.3)±0.2	(−1.3, +0.3)±0.1	3.5
45	(0±1, +0.5 ±0.5)	(2.1, 0.1)±0.2	(−1.5, +0.5)±0.5	3.7
29.9	(−0.3, +0.2)±0.1	(1.6, 0.0)±0.3	(−1.8, 1.0)±0.3	3.6
19.7	(−0.2, +0.1)±0.3	(2.4, −0.3)±0.2	(−1.5, 2.3)±0.1	4.8

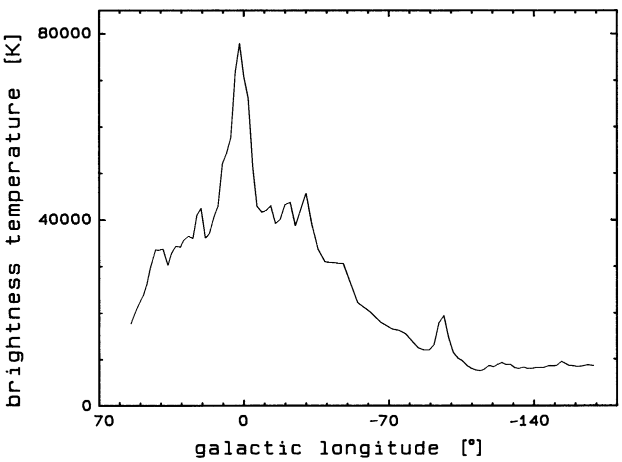

Fig. 1. Profile at 45 MHz along the galactic equator. It shows some galactic features and a strong and broad source near the center. The source at about −95° is Vela Puppis SNR

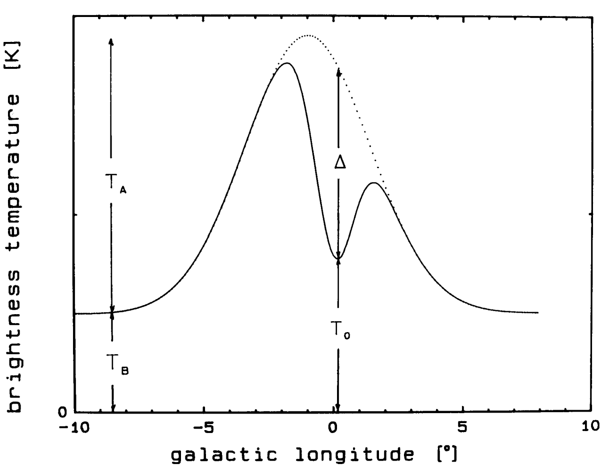

Fig. 2. Schematic expected profile. The curve fitted to the wings is a gaussian

the best of our knowledge, the only work related to the physical properties of the central HII region is that by Matthews et al. (1973 a,b). From symmetry considerations and evidence that the HII region lies behind both the 3 kpc arm and the nuclear disk, those authors conclude that the thermal source is at the galactic center. They also determined an electronic temperature of 9800 K, first from 19.7 MHz free-free absorption and 5.0 GHz continuum emission (1973a), then from 166α hydrogen recombination line observations (1973b). Following Matthews et al. we will assume that the HII region is at the G.C. and we will adopt $T_e = 10^4$ K for its electronic temperature.

Table 3. Expected profile parameters

ν (MHz)	T_B (K)	T_A (K)	T_o (K)	Δ (K)	FWHM[a] (°)
45.0	40500	38000	74000	4500	8.1
85.7	16000	24100	32000	8100	3.2
408	460	390	1950	−1100	3.1

[a] Corrected for beam smoothing

As a first approximation we assume at 408 MHz a simple model consisting of a non-thermal source of amplitude T_A and radius a, concentric with a smaller HII region. The antenna beam (0.8°) is about the angular size of the HII region at 408 MHz. We have also assumed that the two sources are spherical and embedded in a diffuse non-thermal background, at temperature T_B, that pervades the whole Galaxy. The expression for the absorption depth, $\Delta = T_A + T_B - T_o$, can be written:

$$\Delta = \left(\frac{(L-a)}{L+R-2a} T_B + \frac{1}{2} T_A - T_e \right) \left(1 - e^{-\tau}\right) \tag{1}$$

In this equation L is the radius of the Galaxy, assumed 20 kpc, and R is the distance from the Sun to the G.C., taken as 8.5 kpc. Knowing T_A, T_B and Δ at 408 MHz (Table 3), we compute the optical depth τ_{408}; with this optical depth we determine τ_{85} from the relationship $\tau_{85} = \tau_{408}(408/85)^{2.1}$ and from Eq. (1) we finally obtain the absorption depth at 85.7 MHz. The absorption depth so obtained is 11800 K, which is considerably larger than the 8100 K given by the expected profile. Since we consider this difference too large to be attributable to errors we conclude that the preliminary model does not work.

3.2. Proposed model

We have seen that the amplitude of the source defined by the expected profile at 85.7 MHz is insufficient to account for the depth of absorption calculated in the preliminary model. We have then postulated the existence of a non-thermal source with angular size equal or smaller than the trough, that is, than the HII region, and which we define as the *narrow* source. We have assumed it to be non-thermal since an increase in intensity is needed to account for the low frequency observations. It should

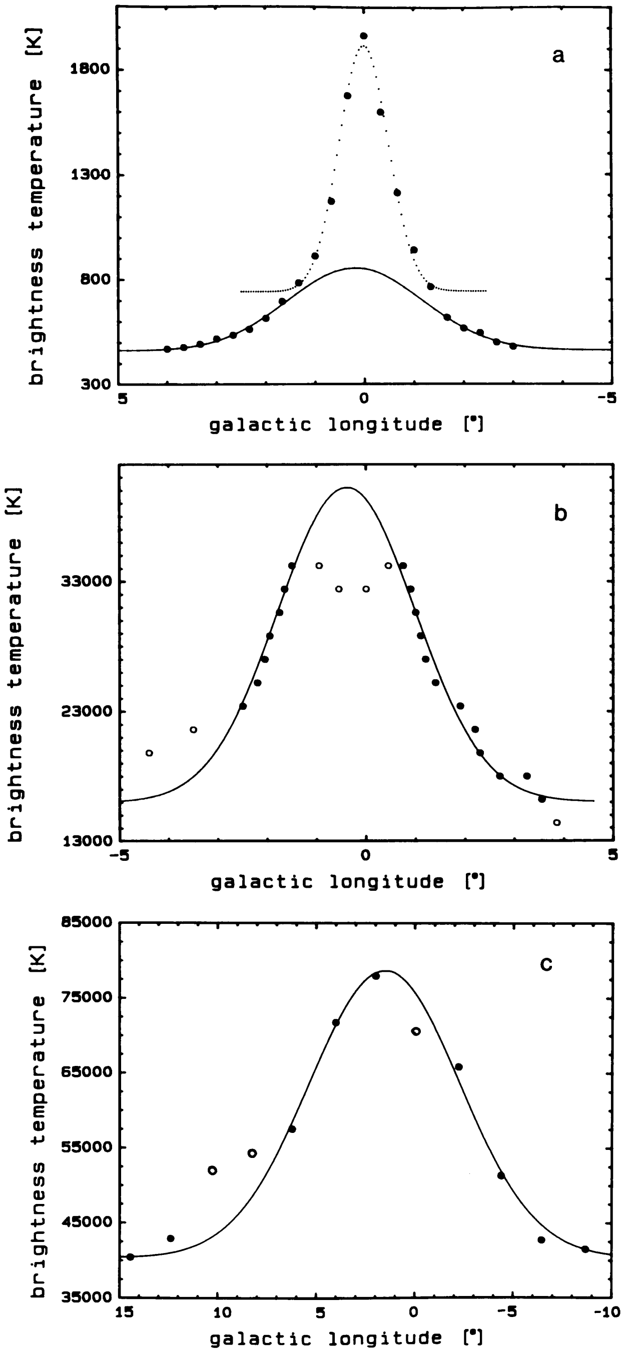

Fig. 3a–c. Gaussian fits. **a** 408 MHz. A good fit is obtained with two gaussians that are associated with the *broad* and the *narrow* sources. **b** 85.7 MHz. The profile was taken along a line slightly inclined to the galactic plane. **c** 45 MHz. Open circles were ignored since they correspond to the radio source W28 and to the absorption dip

be noted that the existence of this source would help in solving the problem found by Little (1974) observing at 408 MHz: modeling the G.C. as a combination of a thermal source, whose temperature he extrapolated from microwave frequencies, and a non-thermal source, whose temperature he extrapolated from 85.7 MHz, he found about 1000 K he could not account for.

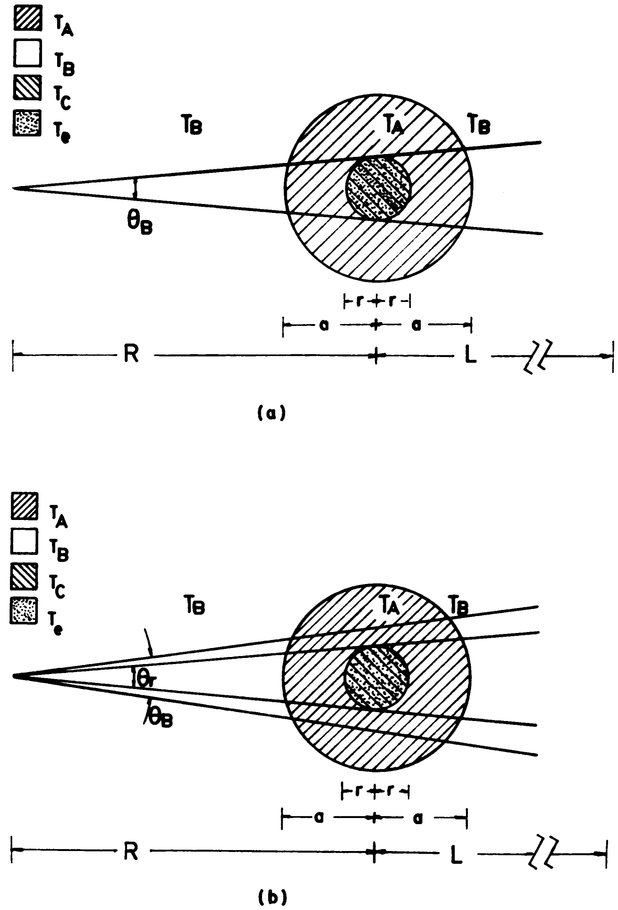

Fig. 4a and b. Geometry of the model. **a** 408 and 85.7 MHz. **b** 45 MHz

Our model consists of four sources, for simplicity assumed spherical and concentric with the G.C., embedded in a diffuse non-thermal background at temperature $T_{\rm B}$ (Fig. 4). The largest of the four is a non-thermal and broad source of radius a and temperature $T_{\rm A}$. Then we have an HII region of radius r and electronic temperature $T_{\rm e}$. Uniformly mixed with the thermal region is a narrow non-thermal source of temperature T_C and size equal or smaller than that of the HII region. The last condition comes from the fact that at 408 MHz the width of the narrow gaussian (0.8°) constitutes an upper bound for the size of the narrow non-thermal source. The narrow source should not be confused with the narrow gaussian since, at 408 MHz, the latter is formed by the narrow source *plus* the HII emission. The model is completed with Sgr A complex, that we will consider as a point source, located at the very center of the Galaxy. The geometry of the model at 85.7 and 408 MHz is shown in Fig. 4a, where θ_B is the antenna beam width. Fig. 4b shows the same model for 45 MHz. Here θ_r is the angular size of the thermal source. We recall that at 85.7 and at 408 MHz θ_B = 0.8°. The equation of transfer valid for any of these two frequencies, and corresponding to Fig. 4a, is:

$$T_o = \frac{(R-a)+(L-a)e^{-\tau}}{L+R-2a} T_B + \frac{(1+e^{-\tau})}{2} T_A + \left(1-e^{-\tau}\right)\left(T_e + \frac{T_C}{\tau}\right) + T_S e^{-\frac{\tau}{2}} \quad (2)$$

Here T_S is the temperature of Sgr A complex and T_o is the temperature observed with the antenna pointing to the center of the absorption region, that is, practically to the G.C. The equation for 45 MHz corresponding to Fig. 4b is:

$$T_o = \left(1 - \frac{k(L-a)(1-e^{-\tau})}{L+R-2a}\right) T_B + \left(1 - \frac{k(1-e^{-\tau})}{2}\right) T_A + k\left(1-e^{-\tau}\right)\left(T_e + \frac{T_C}{\tau}\right) + T_S e^{-\frac{\tau}{2}} \quad (3)$$

where $k = \Omega_r/\Omega_B$ and Ω is solid angle.

In order to check the consistency of our model we need to determine the nature (spectrum) of the narrow and broad sources. We will investigate first the narrow source.

3.2.1. The narrow source

In using Eq. (2) to compute T_C, the temperature of the narrow source, the radius a can be obtained from the angular size (FWHM) given in Table 3 so, since $T_e = 10^4$K, the unknowns are τ and T_S. To determine the optical depth, and following Little(1974), we extrapolate down to 408 MHz the microwave temperatures between 14.5 and 1.41 GHz, quoted by Downes & Maxwell (1966), which fit quite accurately a -1.99 spectral index. The temperature we obtain is 740 K (somehow Little obtained 940 K). From the relation $T = T_e(1 - e^{-\tau})$ and the adopted T_e we get $\tau_{408} = 0.077$. Finally, the contribution T_S from Sgr A complex is obtained from the spectrum given by Pedlar et al. (1989). Even though this spectrum corresponds only to the halo of the complex, it is recognized that the halo makes the most significant contribution, compared to Sgr A East and Sgr A West. At 408 MHz the spectrum gives a flux density of 300 Jy therefore, since the sensitivity of the Haslam et al. survey is 1.42 Jy/K, the temperature contribution from the Sgr A complex is 211 K. Replacing numerical values in Eq. (2) we get T_C = 202 K.

The calculation is similar for 85.7 MHz, except that at this and lower frequencies the Sgr A term is negligible compared to the others. τ_{85} can be computed from τ_{408}. Inserting numerical values in Eq. (2) for 85.7 MHz we obtain T_C = 8220 K.

To compute T_C at 45 MHz with Eq. (3) we need to know τ_{45} and k. From Jones & Finlay (1974) we take $\Omega_r = 1.5° \times 1.0°$, while the antenna beam $\Omega_B = 4.6° \times 2.4°$ so $k = 0.136$. As before, τ_{45} can be computed from τ_{408}. Since at this frequency the contribution from Sgr A is negligible we obtain T_C = 38000 K. This value should be considered as an upper bound only because of the uncertainties in the measurements.

Fig. 5 shows the spectrum of the narrow source that exhibits a spectral index -2.4, clearly indicating a non-thermal source. To check this result we determined from the surveys the spectrum of the well known supernova remnant W28, which is nearby at approximately (6.2°, 0.1°). This supernova is fairly strong, it is clearly seen at 29.9, 34.5 and 85.7 MHz, and it does not seem to be much affected by absorption at 45 MHz and above (Finlay & Jones 1973; Milne & Hill 1969). The spectrum of the peak amplitude observed with 0.8° resolution, shown in Fig. 5, has an index of -2.1, within the range expected for a supernova remnant. Therefore we confirm that the spectral index of the narrow source corresponds to a non-thermal object.

Next we investigate the nature of the broad source.

3.2.2. The broad source

In order to determine the spectrum of the broad source we plotted the amplitude of the expected profiles at 408, 85.7, 45 and 30 MHz. We have assumed that the wings of the profiles, where the gaussian were fitted, have no contributions from the other sources. Unfortunately, it was not possible to have data points with the same angular resolution at the different frequencies. To circumvent this problem we determined spectral indices from data between adjacent frequencies, taking care of equalizing the angular resolutions. Thus, the 408 and 85.7-MHz points have the original 0.8° resolution, and the spectral index they determine is -2.7. To obtain the spectrum between 85.7 and 45 MHz, the 85.7 datum was degraded to the 45-MHz resolution; the point thus degraded and the 45-MHz point gave a spectral index -1.8. A similar procedure was followed for the spectrum between 45 and 30 MHz, where the 45-MHz point was degraded to the 30-MHz resolution obtaining an index +0.3.

The spectrum is shown in Fig. 5 where the piece between 85.7 and 45 MHz was obtained by drawing a line with slope -1.8 through the 85.7 MHz point, and the piece between 45 and 30 MHz was obtained by drawing a line with a slope +0.3 through the *upgraded* 45-MHz point at 73000 K. It should be noticed that the temperature of the point at 85.7 MHz, with 0.8° resolution, does not include the effect of absorption since the source was restored from its non-absorbed flanks; however, the temperature of the lower frequency points, obtained with lower resolution, do include the absorption because the wide beam does not resolve the trough. This effect may partly explain the turn over of the spectrum at the lower frequencies, and lead us to believe that the index -2.7 is representative of the spectrum, therefore we conclude that the broad source is non-thermal. From Fig. 5 we see also that as the frequency decreases thermal absorption sets in at about 45 MHz.

By examining the area around the G.C. in 408, 150, 85, 45, and 30 MHz, we observe that the broad non-thermal source is elongated in the direction of the galactic equator. Fig. 6 shows the 45-MHz data smoothed out to 11°, the resolution of the 30-MHz map. We notice that the contours are fairly elliptical out to 10° from the center, with an axial ratio of 1.7 and the major axis slightly inclined to the equator. The center of symmetry is seen to be offset with respect to the G.C. at (1.9°, 0.0°). A similar situation is present in the 30 MHz map where the center of the contours is located roughly at (1°, -1°). However at 408 and 85 MHz the source is seen centered at (0°, 0°).

Another characteristic of the broad source is that the width of the expected profile, corrected for beam smoothing, increases

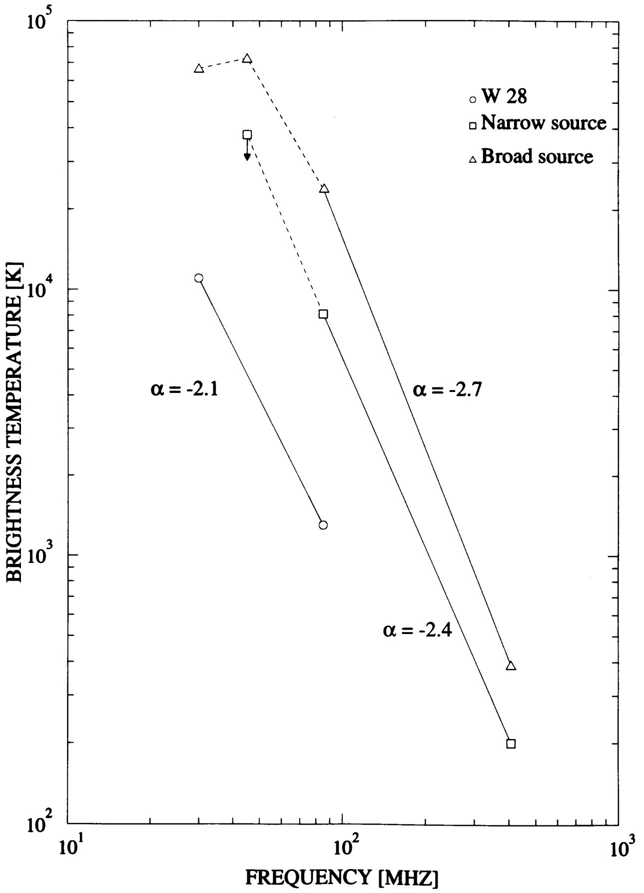

Fig. 5. Spectrum of the broad source (△), narrow source (□) and control source W28 (◯). The explanation for the broken lines is given in the text

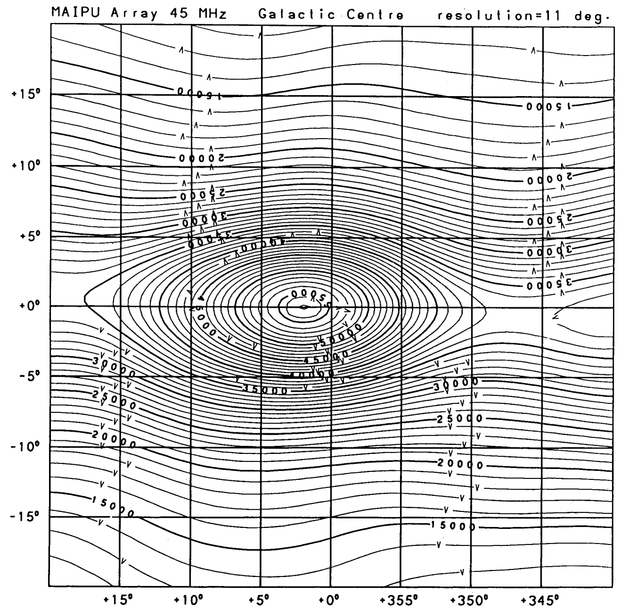

Fig. 6. The 45-MHz data smoothed out with an 11° beam shows the broad source contours. These are fairly elliptical and slightly inclined to the equator

with decreasing frequency; thus, the FWHM at 408, 85.7, 45 and 30 MHz are 3.1°, 3.2°, 8° and 14°, respectively.

It is interesting to know the integrated flux density at 45 MHz. To compute it we integrated numerically the map previously smoothed to 11° (Fig. 6) in order to filter out some sources in the range $6° < l < 10°$, that do not belong to the broad source. The integration was done inside the contour 35000 K which seems a reasonable source boundary (see Fig. 6).The resulting flux density is 4.4 10^{-22} W m^{-2} Hz^{-1}, which gives a spherically radiated power of 9.4 10^{19} W Hz^{-1}. At 45 MHz this power is equivalent to 1740 Crab nebulae and 14 Cass A's. Ilovaiski & Lequeux (1972) have estimated that the luminosity of the Galaxy at 150 MHz is 6 10^{21} W Hz^{-1}. From this value, and using a spectral index of -0.38 (Howell 1970), we derive for 45 MHz a total luminosity of 9.5 10^{21} W Hz^{-1}, which means that at this frequency the broad source emits 1% of the power of our whole Galaxy.

3.2.3. The HII region

We have computed the emission measure (EM) from the relation $\tau = 1.63\,10^5\,\nu^{-2.1}\,T^{-1.35}\,(EM)\,g(\nu,T)$, (where ν is in MHz and EM in pc cm^{-6}), by: a) using $\tau_{408} = 0.077$ derived from the work of Downes & Maxwell (1966); b) adopting $T_e = 10^4$ K from the work of Matthews et al. (1973a,b); and c) assuming $g = 1$. The result gives $EM = 3.6\,10^4$ pc cm^{-6}, in very good agreement with Matthews et al. who obtained 2.6 - 3.2 10^4 pc cm^{-6}.

4. Discussion

A model compatible with the observations consists of four components that for simplicity have been assumed spherical and concentric with the G.C. Table 4 presents the parameters of the revised model. It is difficult to evaluate the errors in temperature as they depend on factors such as calibrations, zero levels, scatter in the measurements, beam smoothing, and others features of the surveys not well known. The accuracy in temperature estimated by the authors of the surveys at 408, 85.7 and 45 MHz are better than 10, 15 and 10%, respectively. In the case of the models presented in this work an additional error derives from fitting gaussians to the data. In order to estimate the goodness of fit we studied the correlation between the measured temperatures and those given by the fit curve. The correlation coefficient for the four fits is equal or better than 0.95, so the corresponding error in temperature shoul be small. We consider that the inhability of the beam to fully resolve the trough at 45 MHz is the main cause of uncertainty in temperature at this frequency. Regarding Sgr A and the HII region, it has been mentioned that the temperatures of the former were taken from Pedlar et al. (1989), assuming it to be a point source, while the adopted parameters for the latter are: electronic temperature 10^4 K (Matthews et al. 1973 a, b), angular size 1.5° x 1.0°, $\Delta l°$ x $\Delta b°$, (Jones and Finlay, 1974), and emission measure 3.6 10^4 pc cm^{-6}, derived by us.

Table 4. Parameters of the revised model

ν (MHz)	T_A^{a} (K)	FWHM[a,b] (°)	T_C^{c} (K)	FWHM[c] (°)	T_{SgrA}^{d} (K)	T_{HII}^{e} (K)	FWHM[e] (°)
408	390	3.1	202	≤ 0.8	211	740	0.8
85.7	24100	3.2	8220	≤ 0.8	$\ll 211$	8700	0.9
45	73000	8.1	≤ 38000		$\ll 211$	10000	1.5[f]

[a] Broad source
[b] Corrected for beam smoothing
[c] Narrow source
[d] Sgr A. From Pedlar et al. (1989). Assuming a point source
[e] HII region
[f] From Jones & Finlay (1974)

The temperature spectrum of the broad source exhibits an index of -2.7, confirming its non-thermal nature. This source has been noticed in the literature as a big bump in temperature profiles taken along the galactic equator, and centered approximately in the G.C.; however this feature has not been thought of as being an individual entity. Several surveys show it with temperature contours very close to ellipses with the major axis lying approximately along the galactic equator. In the 45 and 30-MHz surveys the axial ratio is 1.7 and the center is shifted towards positive longitudes, $1° < l < 2°$. This low frequency shift could be explained if the western peak were observed weakened by the HII region whose absorbing effect extends to the western edge of the broad source as the frequency lowers. This hypothesis would find support from the fact that, as the frequency decreases, the western peak is the one that gets weaker and that its position is the one that changes the most. (See Table 2). Assuming that the broad source is actually centered at (0°, 0°), the above explanation would require a fairly large HII region, large enough to shift by 2° the center of a 8° x 5° structure, while maintaining the symmetry of the observed contours. Even though this is a likely scenario, the apparent displacement of the center of symmetry of the broad source could be real. In this connection it is interesting to recall that the centroid of the G.C. molecular gas has also been found displaced towards positive longitudes, $l \approx 0.7°$ (Bally 1996).

Because it is the brightest object in the radio Galaxy and because of its large size it seems reasonable, in spite of the 2° shift, to think that it is associated with the nuclear region of the Galaxy. In any case, the broad source is such a large object that it does not fit easily into the known types of non-thermal galactic radio sources. Therefore, we suggest it is a major component of our Galaxy and in analogy with the optical structure we would like to define it as the *radio bulge*.

The narrow source is a new finding. Evidence for its emission is seen in the 408-MHz data, however at lower frequencies it is masked by the thermal absorption. A precedent for the existence of this source can be found in the work of Little (1974) who failed to account for all the radiation received at 408 MHz. We have obtained the temperature spectrum of this source which shows an spectral index of -2.4, indicative of its non-thermal nature. We could speculate that the narrow source, as seen at low frequencies, could actually be the $7'$ nuclear halo studied by Pedlar et al. (1989). However, below 408 MHz the computed absorption by the HII region falls short to explain the steep turn over observed in the spectrum, which we have assumed inherently straight.

With the basic physical parameters of the HII region adopted in this work we have computed an emission measure of 3.6 10^4 pc cm^{-6} which is in excellent agreement with the one and only determination found in the literature (Matthews et al. 1973a, b).

5. Conclusions

We have studied the large scale structure around the galactic center in low frequency ($\leq$ 408 MHz) surveys. To account for the observations we propose a model consisting of four spherical sources concentric with the galactic center and embedded in a diffused non-thermal background. The components of the model are:

1. A non-thermal source several degrees wide, with a temperature spectral index -2.7, and prominently seen in surveys below 408 MHz. At 45 MHz it radiates about 9.4 10^{19} W Hz^{-1}, 1% of the whole Galaxy, and we define it as the *radio bulge*. In low resolution maps below 85 MHz, the center of this source appears displaced towards positive longitudes. It is suggestive that a similar situation has been found for the centroid of the molecular gas near the G.C.
2. A non-thermal source, evidence for which is found at 408 MHz, about one degree wide and with a temperature spectral index -2.4.
3. An HII region with an angular extent of 1.5° x 1.0° and an emission measure of 3.6 10^4 pc cm^{-6}.
4. The Sgr A complex.

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