JOURNAL OF THE KOREAN ASTRONOMICAL SOCIETY
29: S199 ∼ S200, 1996

RADIO OBSERVATIONS AT 232 MHz AND MULTIFREQUENCY SPECTRAL STUDIES OF SNR HB21

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I. INTRODUCTION

HB21(G89.0+4.7) is an evolved supernova remnant having an angular size of about $1.5^{\circ}(NS) \times 2.0^{\circ}(EW)$. It was discovered by Brown and Hazard(1953) at 159 MHz and classified tantatively as a rather old supernova remnant by Minknowski(1958).

In this paper, new observations with high resolution at 232 MHz is presented. The observations were carried out with the Miyun Synthesis Radio Telescope(MSRT), Beijing Astronomical Observatory(Wang, 1984). By combining the new data with previously published data of 408 and 1420 MHz(Tatematsu, et al., 1990), 2695 and 4750 MHz (Haslam, et al., 1975 and Reich, et al., 1983), spectral distributions over HB21 are obtained.

II. OBSERVATION AND DATA REDUCTION

The observations were carried out with the MSRT in June 1992. The telescope(Wang, 1984) consists of 28 antennas, each with 9 m in diameter, on an East-West baseline, providing complete baseline coverage from 18 m to 1164 m. The array is divided into two subarrays. Those 16 antennas locating in the central area are the elements of Sub-array A with the same separation of 72 m, the rest 12 antennas, separated in 12 m, standing with 6 dishes on each side of Sub-array A, contribute to Sub-array B. Only 3 antennas in each side of Sub-array A are used in each observation, resulting in 96 interferometer pairs from the combinations $Ai \times Bj(i = 1, 16, j = 1, 6)$. Two day's observation give a complete UV coverage of 192 baselines.

The daily calibration(phase and amplitude) relies on frequent observations of the calibrators. Cyg. A is used as one of the calibrators. It is modeled as double point sources by referring to other frequency data, as it is partly resolved by the longer baselines of MSRT. The constant part of system phases and amplitudes are corrected with an accuracy of about 5^{o} in phase and 10% in amplitude.

As the working frequency, 232 MHz, is low, MSRT data suffer from irregularities of ionosphere and man-made interferences. In general 15 percent of the recorded data are rejected. To remove the effects of interferences and ionospheric irregularities and compensate for zero-offset error, some correction procedure have been developed. The description of reduction of MSRT data in detail can be found in the papers of Zhang et al. (1993 and 1996). After the data-editing mentioned above, the observed data are then sent to AIPS for further reduction of variations of phases and amplitudes in time domain and for map CLEAN.

In the case of MSRT, the short spacings, 0,1,and $2d_0(d_0 = 6m)$ are missed during the observations, causing a weak negative background, the big "bowl". Method has been developed(Zhang, 1995) for compensation of the missing spacings by using interferometer data only.

III. RESULTS

The intensity structure of HB21 agree very well with that obtained from other frequencies. HB21 shows some of the features characteristic of a shell source. The brighter peaks appearing along the inner edge of the source shows an obvious shell structure. The shell and the "rings" near west boundary is broken into many peices.

The map at 232 MHz confirmed some structure features described by Tatematsu(1990). For example, only a small fraction of the total flux originates in the outer ridge and emission from the central part, as seen in projection. Two filaments are clearly seen from the map. One is near $R.A. = 20^{h}47^{m}, Dec. = 50^{\circ}45'$. The other is near $R.A. = 20^{h}45^{m}$, $Dec. = 50^{\circ}30'$. Both of them extend about 20' in length. The second filament, which is more bright at 232 MHz, corresponding to a steep spectral spot may contain the image of a weak extragalactic radio source.

The integral flux density at 232 MHz is about 390 ± 30 Jy measured from the intensity map. BGPW flux system(Baars et al., 1973) is used to scale the flux of the observations. Cyg A and 3C418 are used as the calibrators and their flux densities at 232 MHz are taken as 7944 and 11.4 Jy respectively. By combining this integral flux with that measured at 408 MHz (290 ± 20Jy) and 4750 MHz(110 ± 5Jy) from the maps of Tatematsu(1990) and Reich(1983), integral spectral index of $-0.41 \pm .02$ is obtained by linear fitting.

Although these maps had been compensated for the missing short spacings, they have more or less different zero base-level. So we used T-T plots method to derive further the integral spectral index and spectral variations over the remnant. This method is independent to base level and is sensitive only to the variation of the temperature of object. The integral spectral index derived by this method is $-0.43 \pm .02$ between 232 and 4750 MHz and $-0.44 \pm .02$ between 408 and 4750 MHz. All maps used here were convolved to resolution of $5.2' \times 4.7'$.

To get spectral spatial variation a method has been developed, following Anderson and Rudnick(1993). It is an extension of the T–T plot method and is called the *convolution differential-spectral-index* technique. (Zhang 1995). Spectral spatial variations of HB21 at frequency intervals 232-4750 MHz, 408-4750 MHz, and 232-2695 MHz have been calculated by using this new method. The spectral index of HB21 is 2.55 at southeast, falling to 2.35 at northwest.

A ring-shape structure of steeper spectra is clearly visible from the spectral distribution map. It surround the central flat spectrum area which contains the X-ray emission area(from ROSAT released data base). Two spectral spots are found. one is near the center, while another is at the northwest corner of the remnant.

IV. DISCUSSION

According to the paper of Tatematsu et al.(1990), there are gas of HI and CO along the east and south boundary and HB21 is interacting with the gas. Around the flat spectrum region, i.e. northwest part of HB21 shell, no so much gas surrounded. The central flat spectrum regions are surrounded by a ring-shape structure of steeper spectrum. They are not in coincidence with the optical filaments, but are well in agreement with the structure of X-ray(Leahy, 1987, and ROSAT data). This phenomenon may be caused by post-shock reheating of the interstellar medium. HB21 is an evolved SNR. The ISM in the post-shock region can be reheated up to 10^7 K, so that X-ray from the hot plasma and thermal radio emission could be radiated from this region. The Galactic background emission is probably another reason which is responsible for the spectral variations from southeast to northwest of HB21, as the direction along which the spectral index is decreasing, is nearly in the direction of the increasing Galactic latitude. There are two spectral spots at 232 MHz in the remnant. The one near the center is enhanced at 232 MHz.

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