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A VLA ARCHIVE OBSERVATION OF THE YOUNGEST KNOWN GALACTIC SUPERNOVA REMNANT G1.9+0.3

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RESUMEN

Presentamos el análisis de una observación de archivo sin publicar hecha con el Very Large Array a 1.49 GHz en 1989 hacia la remanente de supernova G1.9+0.3, la más joven conocida en la Galaxia. Esta observación concuerda con la evolución temporal del tamaño angular reportada anteriormente. Derivamos una tasa de expansión angular de $0.46 \pm 0.11\%$ por año y estimamos una edad de $220\pm^{70}_{45}$ años comparando las imágenes de 1985 y 1989.

ABSTRACT

We present the analysis of an unpublished VLA archive observation made at 1.49 GHz in 1989 toward the supernova remnant G1.9+0.3, the youngest such Galactic object known. This observation agrees with the time evolution in angular size previously reported. We derive an expansion rate of $0.46 \pm 0.11\%$ per year and an age of $220\pm^{70}_{45}$ yr for the remnant by comparing the 1985 and 1989 images.

Key Words: ISM: individual (G1.9+0.3) — supernova remnants

1. INTRODUCTION

In a remarkable result, Green et al. (2008) and Reynolds et al. (2008) reported the fast expansion ($13{,}000\pm1{,}000$ km s^{-1} at an assumed distance of 8.5 kpc) of the compact supernova remnant G1.9+0.3, concluding that, with an age of order 100 years, it is the youngest such object in the Galaxy. Obviously, any past observation of this source becomes now particularly valuable since they will help to better characterize the parameters of supernova remnants in a very young stage.

In this paper we present the analysis of archive 1.49 GHz continuum observations made with the Very Large Array (VLA) in the B configuration toward G1.9+0.3 in two epochs: 1985 April 16 (epoch 1985.29) and 1989 April 29 (epoch 1989.33). The first epoch has been analyzed and discussed in detail by Green et al. (2008) and Reynolds et al. (2008) since it constitutes the first epoch of their expansion measurements. Reynolds et al. (2008) compared the VLA 1.49 GHz observations of 1985 April 16 with Chandra observations taken during 2007 February 10 and March 3 with the ACIS-S CCD camera, while Green et al. (2008) compared the same 1985 VLA observations with new VLA observations of similar angular resolution $\sim 10'' \times 4''$, but taken at a different frequency (4.86 GHz) on 2008 March 12.

Additional radio data for G1.9+0.3 has been presented by De Horta et al. (2008), who discuss observations made in 1993 using the Australia Telescope Compact Array (ATCA) at 6 cm and confirm the expansion rate of $\sim$0.65% per year found by Green et al. (2008) between 1985 and 2008. However, the De Horta et al. (2008) results are derived from images with quite different uv coverage. Murphy, Gaensler, & Chatterjee (2008) present a radio light curve for G1.9+0.3 based on 25 epochs of 843 MHz observation with the Molonglo Observatory Synthesis Telescope, spanning 20 yr from 1988 to 2007. They find that the flux density has increased at a rate of $1.22\pm^{0.24}_{0.16}\%$ per year, supporting the suggestion of Green et al. (2008) that G1.9+0.3 is undergoing a period of magnetic field amplification.

In this paper we present the analysis of VLA archive data taken in 1989 April 29 with the same frequency and angular resolution as the data of 1985 April 16. To our knowledge, the 1989 data are unpublished. Our analysis allows a more reliable comparison since the data have the same frequency and angular resolution, but it has the disadvantage that

TABLE 1

1.49 GHZ ARCHIVE DATA FOR G1.9+0.3

Epoch	Project	Time[a] (min)	Phase Calibrator	Bootstrapped Flux(Jy)	Beam Angular Size[b]
1985 April 16 (1985.29)	AG184	25	B1829-106	0.92±0.01	$10\farcs6 \times 5\farcs6$; -6°
1989 April 29 (1989.33)	AB515	6	B1748-253	1.21±0.01	$10\farcs6 \times 5\farcs1$; -14°

[a]Integration time on source.

[b]Major axis × minor axis; position angle for images with ROBUST = 5. The final images were made with a restoring beam of $12\farcs0 \times 6\farcs5$; $PA = 0^\circ$.

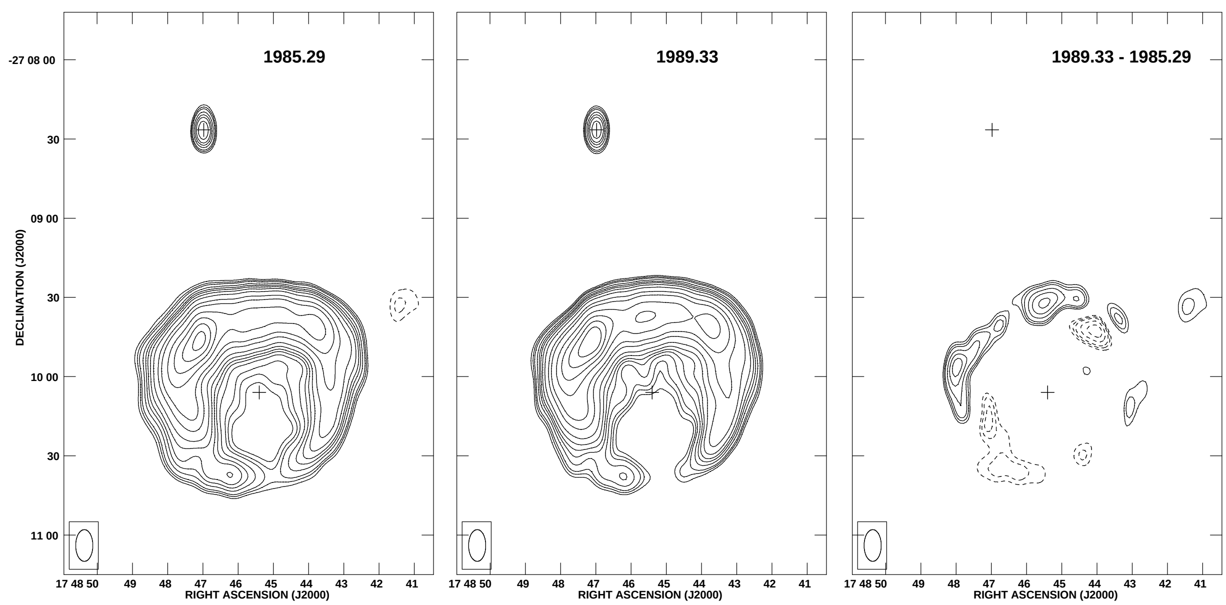

Fig. 1. Contour images of the 1.49 GHz continuum emission from G1.9+0.3 for 1985.29 (left) and 1989.33 (right). The difference image, taken to be the 1989.33 image minus the 1985.29 times 1.05, is shown in the right panel. The contours are 10, −8, −6, −5, −4, 4, 5, 6, 8, 10, 12, 15, 20, 30, 40, 60, 80, 100, and 120 times 0.4 μJy beam^{-1}. The cross in the northern part of the images marks the position of a field source. The cross in the southern part of the images marks the centroid of the radio emission associated with G1.9+0.3, from Green et al. (2008). The half power contour of the restoring beam ($12\farcs0 \times 6\farcs5$; $PA = 0^\circ$), is shown in the bottom left corner of the panels.

the time baseline is small, only 4.04 years. Although the 1989 data are constituted of only two 3-minute integrations separated by 1.5 hours they have excellent quality and allow a comparison with the previous epoch.

2. DATA REDUCTION

The archive data were edited and calibrated using the software package Astronomical Image Processing System (AIPS) of NRAO. Cleaned maps were obtained using the task IMAGR of AIPS and the ROBUST parameter (Briggs 1995) of this task set to 5, to optimize sensitivity. The observational parameters of the two epochs are given in Table 1.

3. RESULTS

3.1. *Flux Densities*

The flux densities obtained by us at 1.49 GHz are 0.565±0.078 Jy and 0.646±0.046 Jy for the epochs 1985.29 and 1989.33, respectively. These flux densities were obtained from the images using the task IMSTAT of AIPS and estimating the errors following Beltrán et al. (2001). However, these data were taken in the B configuration at 1.49 GHz, where the largest angular scales detectable by the array are only a factor of 2 larger than G1.9+0.3. We then expect to have poor sampling of the uv plane close to the zero spacing and that the flux densities reported above are underestimating the real values. Additional measurements at 1.4 GHz (0.748±0.038 Jy; epoch 1996.47; Condon et al. 1998) and at 1.425 GHz (0.935±0.047 Jy; epoch 2008.20; Green et al. 2008) are reported in the literature.

3.2. *Images*

To compare the angular size of the SNR at the two epochs we made images with the same restoring beam of $12\rlap{.}''0 \times 6\rlap{.}''5$; $PA = 0°$. This value is comparable to the synthesized beams of the two epochs (see Table 1). We show in Figure 1 the images of G1.9+0.3 for the two epochs (1985.29 and 1989.33), as well as a difference image (1989.33−1985.29). The difference image shows evidence of expansion, with positive contours in the outer parts of the remnant and negative contours in the inner parts. Unfortunately, the lack of azimutal symmetry of the nebula does not produce a clear shell in the difference image, as observed for example in some planetary nebulae (e. g. Guzmán, Gómez, & Rodríguez 2006). Following Green et al. (2008) we averaged the emission over all azimuths, using the task IRING of AIPS. The central position of these rings was the centroid of the radio emission associated with G1.9+0.3, $\alpha(2000) = 7^h\ 48^m\ 45\rlap{.}^s4; \delta(2000) = -27°\ 10'\ 06''$, from Green et al. (2008). The shell profiles for the two epochs, normalized to the peak value of 1989.33 by multiplying the 1985.29 profile by 1.05, are shown in Figure 2. The 1989.33 profile is slightly displaced to larger radii with respect to the 1985.29 profile. In Figure 2 we also show the difference of the two profiles, that shows the S-shaped profile indicative of expansion. Analyzing these profiles under the assumption that they are Gaussian, we find a displacement of $0\rlap{.}''57 \pm 0\rlap{.}''14$ between the two epochs. Since the peak of the shell is expected to have a radius of $31''$ in 1989 (Green et al. 2008), this implies an expansion rate of $0.46 \pm 0.11\%$ per year and an age of $220\pm^{70}_{45}$ yr for the remnant (assuming a constant expansion velocity and with respect to the 1989 epoch). This age is somewhat larger than the value of 150 yr estimated by Green et al. (2008). Additional observations are required to better estimate the age of this SNR, but it is certainly a very young object.

This is the first determination of the expansion of the SNR made from data at the same frequency, since the determination of Reynolds et al. (2008) was made comparing VLA (radio) and Chandra (X-ray) images and that of Green et al. (2008) was made comparing a 1.49 GHz image with a 4.86 GHz image (both made with the VLA).

The NW extension found by Green et al. (2008) in their 2008 image made at 4.9 GHz is not present in the 1989 image made at 1.49 GHz and presented here (Figure 1). This implies that the extension must have appeared after 1989.

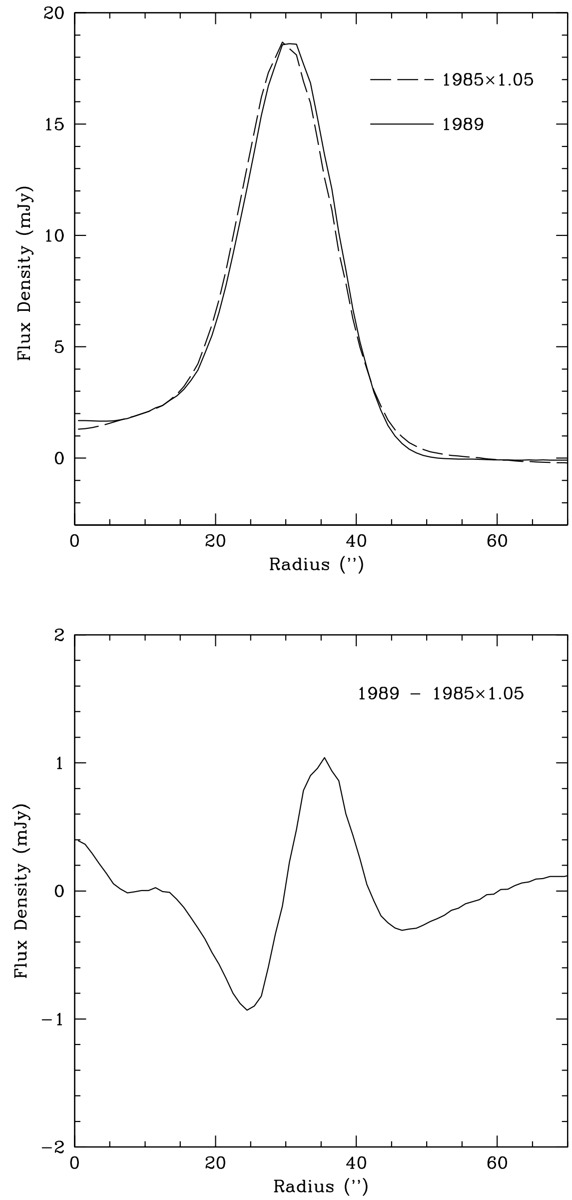

Fig. 2. (Top) Shell profiles for the 1.49 GHz continuum emission from G1.9+0.3 for 1985.29 (dashed line) and 1989.33 (solid line). The peak intensities have been normalized by multiplying the 1985.29 profile by 1.05. Bottom: Difference of the shell profiles.

4. CONCLUSIONS

Our main conclusions are as follows.

(1) We present the analysis of VLA archive data of the young supernova G1.9+0.3 taken at 1.49 GHz in 1989.

(2) This data point agrees well with the evolution observed in observations taken at the same or similar frequencies at other epochs and confirms the angular expansion previously reported.

(3) We derive an expansion rate of $0.46 \pm 0.11\%$ per year and an age of $220\pm^{70}_{45}$ yr for the remnant from the 1985 and 1989 data. This is the first determination of the expansion of the SNR made from data at the same frequency, since the determination of Reynolds et al. (2008) was made comparing VLA (radio) and Chandra (X-ray) images and that of Green et al. (2008) was made comparing a 1.49 GHz image with a 4.86 GHz image (both made with the VLA).

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