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ON THE DISTANCE TO THE BRIGHT NONTHERMAL RADIO SOURCES IN THE DIRECTION OF AN EXTRAORDINARILY MASSIVE CLUSTER OF RED SUPERGIANTS

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RESUMEN

Un cúmulo extraordinariamente masivo de supergigantes rojas ha sido recientemente reportado en la dirección de las coordenadas galácticas $l = 25.^{\circ}3$; $b = -0.^{\circ}2$. Este cúmulo está asociado con una fuente de rayos X, con una fuente de muy alta energía de rayos γ, y con tres fuentes de radio brillantes y no térmicas. La probabilidad *a priori* de que estas asociaciones sean sólo coincidencias en la línea de visión es muy pequeña. Sin embargo, hemos analizado datos del archivo del VLA y encontramos del espectro de absorción de H I de las tres fuentes de radio que son extragalácticas y por lo tanto no asociadas directamente con el cúmulo galáctico.

ABSTRACT

An extraordinarily massive cluster of red supergiants has been recently reported in the direction of the galactic coordinates $l = 25.^{\circ}3$; $b = -0.^{\circ}2$. This cluster is associated with an X-ray source, a very high-energy γ-ray source, and three bright non-thermal radio sources. The *a priori* probability of these associations being only line-of-sight coincidences is very small. However, we have analyzed VLA archive data taken toward these three radio sources and find from their H I absorption spectra that they are extragalactic and thus not directly associated with the galactic cluster.

Key Words: **RADIO CONTINUUM: GALAXIES — STARS: SUPERGIANTS**

1. INTRODUCTION

Recently, Figer et al. (2006) reported the discovery of an extraordinarily massive young cluster of stars in the Galaxy, having an inferred total initial cluster mass of 20,000 to 40,000 $M_{\odot}$, comparable to the most massive young clusters in the Galaxy. Using *IRMOS*, *2MASS*, and *Spitzer* observations, they concluded that there are 14 red supergiants in the cluster, compared with five in NGC 7419 (Caron et al. 2003), previously thought to be the richest Galactic cluster of such stars.

Furthermore, they find that the cluster is associated with an X-ray source (detected by *ASCA* and *Einstein*), a recently discovered very high energy γ-ray source (detected by *INTEGRAL* and *HESS*), and several non-thermal radio sources, suggesting that these objects are likely related to recent supernovae in the cluster. The non-thermal sources are quite bright and an H I absorption spectrum toward them could be used to estimate their distance. Here we present the analysis of VLA archive data that allows such a distance determination.

2. OBSERVATIONS AND DISCUSSION

The H I and 20 cm continuum observations were taken from the archive of the Very Large Array (VLA) of the NRAO[1] The observations were taken on 2000 April 6. The VLA was then in the C configuration, providing an angular resolution of about 20″ for images made with natural weighting. The absolute amplitude calibrator was 1331+305 (with an

[1]The National Radio Astronomy Observatory is operated by Associated Universities Inc. under cooperative agreement with the National Science Foundation.

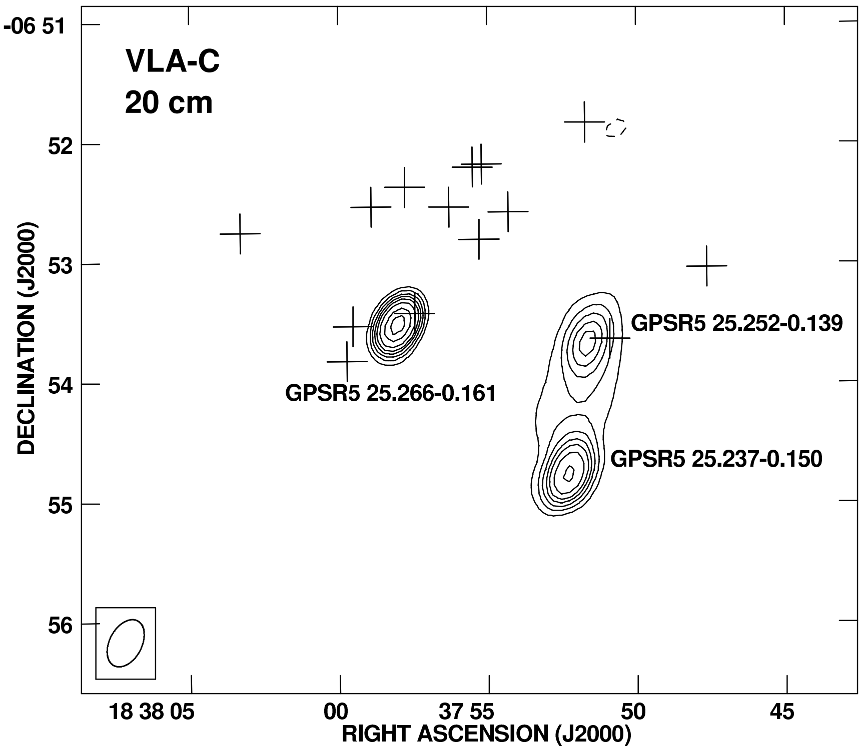

Fig. 1. VLA contour image of the continuum emission at 20 cm of the region of the cluster of red supergiants. Contours are −4, 4, 6, 8, 10, 12, 15, 20, and 25 times 13 mJy beam^{-1}, the rms noise of the image. The image was made from line-free channels of the data and it is corrected for the primary beam response. The names of the three bright non-thermal sources are indicated in the figure. The positions of the fourteen red supergiants reported by Figer et al. (2006) are marked with crosses. The half-power contour of the synthesized beam ($25\farcs3 \times 16\farcs1$; PA = −28°) is shown in the bottom left corner of the map.

adopted flux density of 14.7 Jy at 1.4 GHz), and the phase calibrator was 1743−038, with a bootstrapped flux density of 2.18±0.01 Jy. The data were edited and calibrated using the software package Astronomical Image Processing System (AIPS) of NRAO.

2.1. *Continuum*

A natural-weight continuum image, made using the line-free channels of the data, is shown in Figure 1. The three continuum sources, as well as their close association with the supergiant stars, are evident in this image. The spectral indices of these sources indicate a non-thermal nature (Becker et al. 1994). The positions and flux densities of the sources are given in Table 1. In addition to the three non-thermal sources, we have also included in this table the well known H II region G25.38–0.18 (e.g., Wink, Wilson, & Bieging 1983; Churchwell, Walmsley, & Cesaroni 1990) that appears projected about 8′ to the NE of the cluster. This H II region is the brightest component of the W42 complex. We include this source in the discussion in order to have an H I absorption spectrum of a confirmed Galactic source for comparison.

The *a priori* probability of finding a background source with a 20 cm flux density of ∼ 0.4 Jy (the average flux density of the three non-thermal sources) in a region of about 4′ × 4′ is very small. Following Windhorst et al. (1993), we estimate this probability to be only ∼ 0.0005. This suggests a real association between the cluster and the radio sources.

2.2. *H I Line*

However, these three non-thermal radio sources are included among the 54 bright, compact radio sources used by Kolpak et al. (2002) in their study of the radial distribution of cold hydrogen in the Galaxy. Although these authors do not show H I absorption spectra of these sources, they note that all sources considered in their analysis are identified as extragalactic continuum sources by the presence of significant absorption at local standard of rest (LSR)

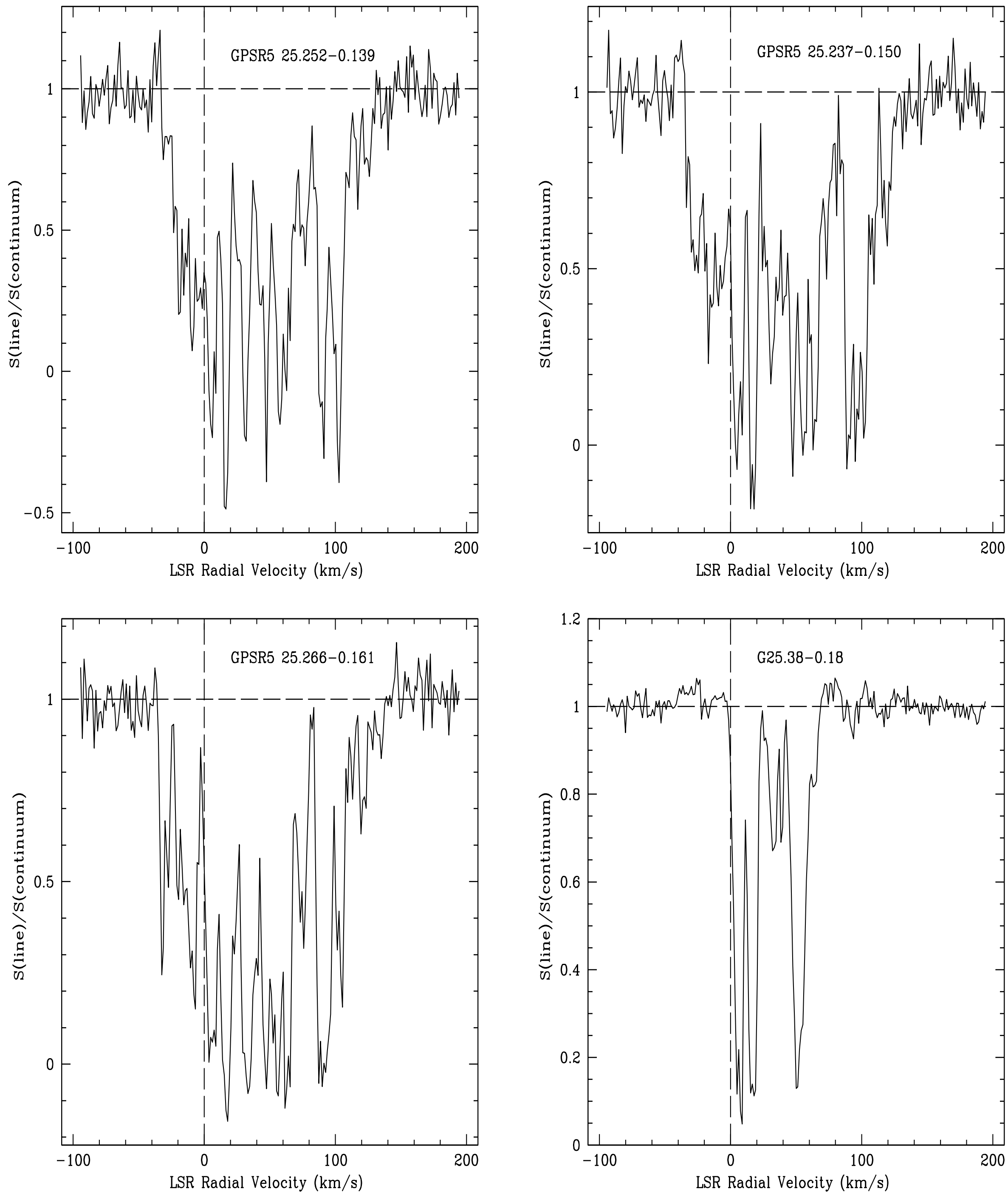

Fig. 2. 21 cm H I absorption spectra for the four sources listed in Table 1, plotted as a function of LSR radial velocity. The measured spectra were divided by the continuum level, so that each point in the spectra shown equals $\exp(-\tau_v)$, where τ_v is the optical depth of the H I absorption at the radial velocity v. The horizontal dashed line is drawn at $S(line)/S(continuum) = 1$ and the vertical dashed line is drawn at an LSR radial velocity of 0 km s^{-1}. Note that in the three non-thermal sources (GPSR5 25.252–0.139, GPSR5 25.237–0.150, and GPSR5 25.266–0.161) there is significant absorption from gas beyond the solar circle (negative velocities). In contrast, the H II region G25.38–0.18 does not show absorption at negative velocities, indicating that the source is located inside the solar circle.

TABLE 1

BRIGHT RADIO SOURCES NEAR THE MASSIVE CLUSTER OF RED SUPERGIANTS

Source	Position α(J2000)	Position δ(J2000)	20 cm Flux Density (Jy)	H I Spectrum Box ($\Delta\alpha \times \Delta\delta$)	Proposed Identification
GPSR5 25.252–0.139	18 37 51.7	−06 53 40	0.38±0.04	24″ × 40″	Background Extragalactic
GPSR5 25.237–0.150	18 37 52.3	−06 54 46	0.44±0.04	16″ × 24″	Background Extragalactic
GPSR5 25.266–0.161	18 37 58.0	−06 53 31	0.37±0.04	16″ × 24″	Background Extragalactic
G25.38–0.18	18 38 15.1	−06 48 01	3.92±0.13	24″ × 40″	Galactic H II Region

velocities of less than -10 km s^{-1}. This negative velocity absorption is caused by relatively remote material in the Galaxy, located outside the solar circle.

To investigate in detail the H I absorption spectra, we made line cubes of the region and produced spectra toward the sources in an angular box containing most of the bright central emission of the sources. The dimensions of these boxes are given in Table 1. The spectra have a velocity resolution of 2.6 km s^{-1} and they are shown in Figure 2.

As can be seen in Fig. 2, the three non-thermal sources (GPSR5 25.252–0.139, GPSR5 25.237–0.150, and GPSR5 25.266–0.161) show H I absorption in an LSR velocity range of ~ -30 to $+120$ km s^{-1}, while the H II region G25.38–0.18 shows H I absorption in the more limited range of ~ 0 to $+60$ km s^{-1}. To interpret the implications of these absorption spectra, we use the galactic rotation model of Brand & Blitz (1993) and assume that the H I disk of the Galaxy has an outer radius of 13.4 kpc (Goodwin, Gribbin, & Hendry 1998). In Figure 3 we show the expected LSR velocity as a function of distance to the Sun in the direction of the cluster of red supergiants.

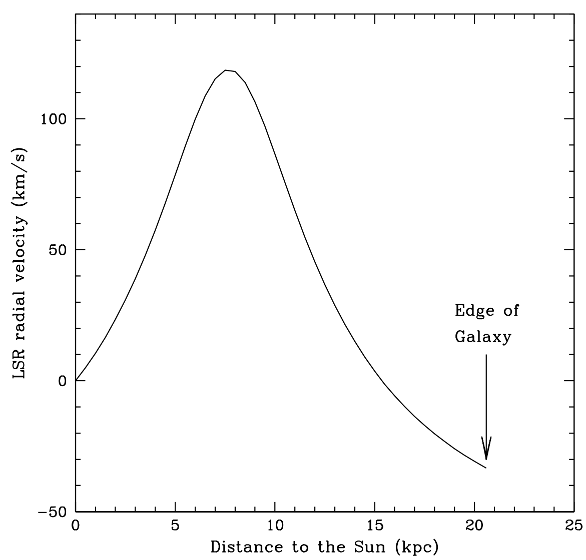

Fig. 3. LSR radial velocity as a function of distance to the Sun in the direction of the cluster of red supergiants. The negative values of the LSR radial velocity come from gas beyond the solar circle. The arrow marks the distance to the Sun where the edge of the Galaxy is located.

2.3. *Distances*

Figer et al. (2006) estimate the distance to the cluster of red supergiants to be 5.8 kpc. For this, they associate a 1612 MHz OH maser (OH 25.3–0.16) with LSR radial velocity of $+102.2$ km s^{-1} with the cluster. This association is well justified, since the maser is located near the center of the cluster. However, these masers are usually produced in the winds of evolved stars and typically exhibit a double-peaked spectrum, with the systemic velocity of the star at the middle of the velocity of the two lines. In the case of OH 25.3–0.16 only one of the lines was detected, implying that the true systemic velocity of the star is either redshifted or blueshifted with respect to the value of $+102.2$ km s^{-1}. Additional observations of this maser are required to refine the distance to the cluster.

In the case of the H II region G25.38–0.18, the lack of absorption at negative velocities (see Fig. 2) indicates that it is inside the solar circle. Furthermore, the lack of H I absorption at LSR velocities more positive than $+60$ km s^{-1} suggests a distance of 4.1 kpc. This H II region has reported H76α emission at an LSR velocity of $+58.9\pm0.4$ km s^{-1}, implying a distance of also 4.1 kpc.

In contrast, the H I absorption at negative LSR velocities of order -30 km s^{-1} present in the three non-thermal sources (see Fig. 2) indicates that they are outside the solar circle. From Fig. 3 we see that the expected LSR velocity for gas at the outer edge of the Galaxy in that direction is also -30 km s^{-1}, implying that the sources are outside of the Galaxy, most probably at extragalactic distances.

3. CONCLUSIONS

We have presented an analysis of the H I absorption spectra toward three bright non-thermal radio sources associated in the plane of the sky with the extraordinarily massive cluster of red supergiants recently reported by Figer et al. (2006). Although the *a priori* probability that these sources are background extragalactic objects is very small, the LSR velocity range of the H I absorption seems to indicate this is the case. We thus confirm the classification of these sources as extragalactic, as first noted by Kolpak et al. (2002). Further research is required to understand the unlikely association of this remarkable cluster with radio, X-ray, and γ-ray sources.

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