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THE BLISTER H II REGION ASSOCIATED WITH GM24

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RESUMEN

Presentamos observaciones hechas con el *VLA* de la región H II ultracompacta GM24 en la línea H76α y el continuo a 2-cm con resolución angular de $\sim 1''$. El mapa de radiocontinuo muestra una morfología de ampolla, con la orilla sureña acotada abruptamente. Hacia el norte la fuente de radio se extiende $\sim 15''$ y se conecta con la nebulosidad óptica. Existe también evidencia de un gradiente de velocidad sobre la faz de la región H II, con la parte norte corrida al azul por 6-8 km s^{-1} respecto a la parte sur. Concluimos que GM24 es una región H II tipo ampolla que ha brotado de su nube molecular materna y está en la fase champaña.

ABSTRACT

We present *VLA* observations of the ultracompact H II region GM24 in the H76α line and 2-cm continuum with an angular resolution of $\sim 1''$. The ratio continuum shows a blister morphology, with the southern edge sharply bounded. The northern parts of the radio source extend over $\sim 15''$ and connect with the optical nebulosity. There is also evidence for a velocity gradient across the face of the H II region, with the northern part blueshifted by 6-8 km s^{-1} with respect to the southern part. We conclude that GM24 is a blister H II region that has bursted out of its parent molecular cloud and is undergoing the champagne phase.

Key words: H II REGIONS – MOLECULAR CLOUDS – NEBULAE

I. INTRODUCTION

GM24 is an optical emission nebula of cometary shape that was first reported by Gyulbudaghian and Magakian (1977) and that appears as PP85 in the catalog of Parsamian and Petrosian (1979). Torrelles *et al.* (1983) found that the nebula is associated with a hot ($T_K \simeq 35$ K), massive ($\sim 10^4$ $M_\odot$; Tapia *et al.* 1985) molecular cloud. Tapia *et al.* (1985) undertook a radio, IR, and optical study of the region and concluded that the optical nebula is most probably the visible part of an embedded H II region that is starting to burst out of the cloud.

In this paper, we present high-angular resolution interferometric observations of the associated radio H II region (Tapia *et al.* 1985) in the H76α line and adjacent continuum at 2-cm. Our main goal was to study better the relationship between the radio and optical H II regions and the molecular cloud.

II. OBSERVATIONS

The observations at 14.7 GHz of the H76α radio recombination line and the adjacent continuum were made with the Very Large Array (*VLA*) of the National Astronomy Observatory[1] in 1986 October 4. The array was in the B/C hybrid configuration, providing an angular resolution of $\sim 1''$ at 2-cm for southern sources.

1. NRAO is operated by Associated Universities, Inc., under contract with the National Science Foundation.

We observed the H76α and He76α with 15 channels of 781.25 kHz (16.0 km s^{-1}), after applying on-line Hanning smoothing. The *VLA* spectral line system also provides a continuum channel that contains the average of the central 75% of the total available bandpass, which for our observations was 12.5 MHz. The data were calibrated and edited using the standard *VLA* programs.

III. RESULTS

a) *Continuum Map*

The self-calibrated continuum map of GM24 made with the continuum channel using uniform weighting is shown in Figure 1. There is a relative sharp decrease in the emission to the south, while to the north the source extends more smoothly. This is the characteristic shape of the "blister" H II regions, objects that form near the edge of a molecular cloud and are ionization-bounded in the direction of the molecular cloud and density-bounded to the outside. A considerable number of blisters H II regions have been reported in the literature since the suggestion by Zuckerman (1973) that Orion A is a blister H II region. The reviews of Habing and Israel (1979) and Yorke (1986) discuss the blister phenomenon in detail. The faint extension to the north in Figure 1 connects with the optical nebulosity (GM24), as it is shown in Figure 2. The blister morphology and orientation as well as the connection between the radio

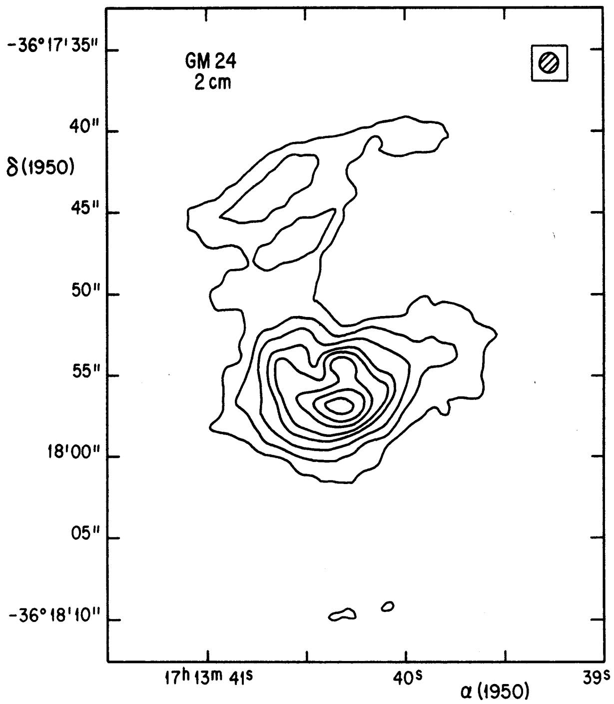

Fig. 1. Self-calibrated map of the 2-cm continuum emission from the compact H II region associated with GM24. Contours are −0.02, 0.02, 0.05, 0.1, 0.2, 0.3, 0.5, 0.7, and 0.9 of the peak value of 190 mJy/beam.

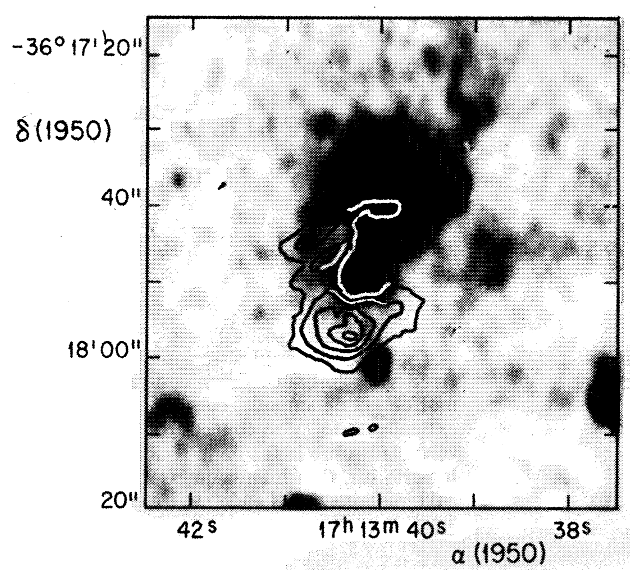

Fig. 2. Selected contours of the self-calibrated map at 2-cm superposed on a copy of the Short Red UK Schmidt I/SR Atlas. Note that the northern part of the radio ultracompact H II region connects with the visible nebulosity.

core and the optical nebulosity confirm the suggestion of Tapia *et al.* (1985) that GM24 is the visible part of an obscured H II region that is beginning to emerge from its molecular cloud.

The cleaned flux in the solid angle shown in Figure 1 is 2.7 ± 0.2 Jy. Tapia *et al.* (1985) measured 3.6 ± 0.2 Jy at 4.9 GHz. The flux measurements are consistent with an optically-thin ($S_\nu \propto \nu^{-0.1}$) H II region above 4.9 GHz. The continuum parameters of the compact H II region associated with GM24 are given in Table 1, following the formulation of Schraml and Mezger (1969) for a homogeneous sphere with electron temperature of 10^4 K.

The detected radio source is associated with the infrared source IRS 2 (Tapia *et al.* 1985). We did not detect radio sources (within an upper limit of 4 mJy) at the positions of the bright infrared sources IRS 1 and 3. At present it is unclear if the sources are associated with less evolved stars that have not yet developed a detectable H II region. The possibility that they are infrared reflection nebulae could be addressed with a polarimetric study.

b) *Line Emission*

Line maps were obtained by subtracting from the line plus continuum maps an average continuum map formed with six channels without evident line emission. An average spectrum was obtained by integrating the line emission in each map. This spectrum is shown in

TABLE 1

CONTINUUM AND LINE PARAMETERS OF THE COMPACT H II REGION ASSOCIATED WITH GM24

Right Ascension (1950)	$17^h\ 13^m\ 40^s.34 \pm 0^s.02$
Declination (1950)	$-36°\ 17'\ 56''.0 \pm 0''.3$
Flux Density at 14.7 GHz	2.7 ± 0.2 Jy
Angular Diameter at Half Maximum	∿ 4″
Adopted Distance	2.0 kpc[a]
Physical Diameter at Half Maximum	0.04 pc
Electron Density	$3.8 \times 10^4\ cm^{-3}$
Mass of Ionized Gas	$9.2 \times 10^{-2}\ M_\odot$
Emission Measure	$8.3 \times 10^7\ cm^{-6}\ pc$
Optical Depth at 14.7 GHz	0.10
Required Number of Ionizing Photons	$1.1 \times 10^{48}\ s^{-1}$
Equivalent ZAMS Star	O9
S_L (H76α)	328 ± 14 mJy
Δv (H76α)	$42.8 \pm 2.4\ km\ s^{-1}$
v_{LSR} (76α)	$-10.1 \pm 0.8\ km\ s^{-1}$
Electron Temperature	10 000 ± 1 000 K

a. Torrelles *et al.* (1983).

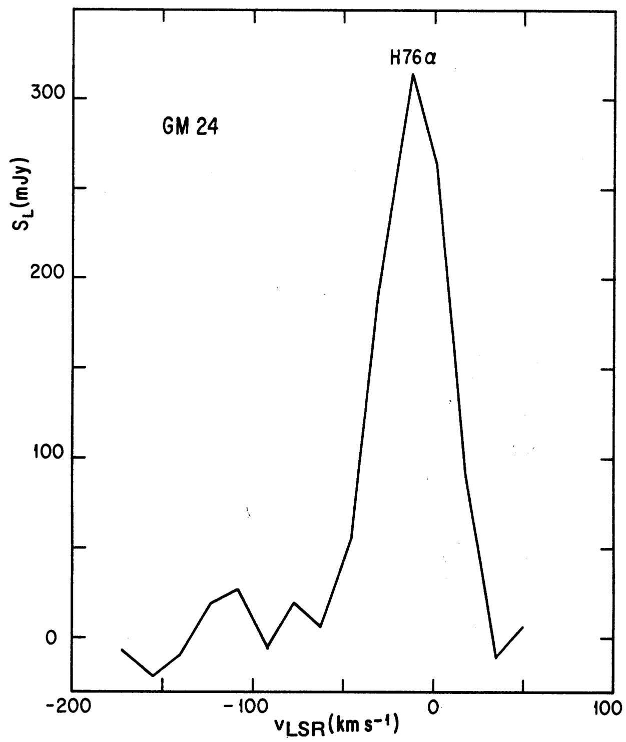

Fig. 3. Integrated spectrum of the H76α emission from the compact H II region associated with GM24.

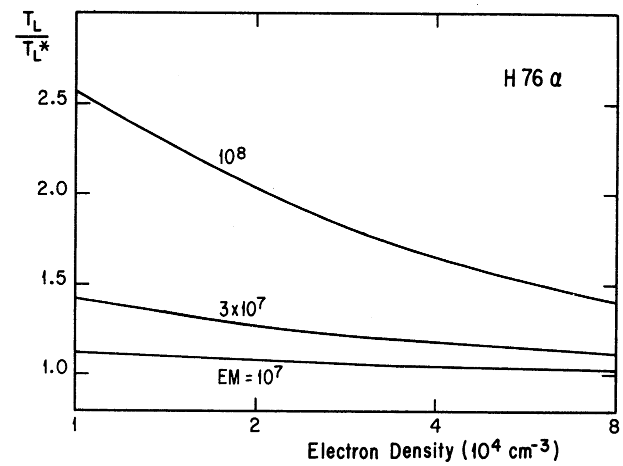

Fig. 4. The ratio of line temperature to LTE line temperature, T_L/T_L^*, as a function of electron density for emission measures of 10^7, 3×10^7 and 10^8 cm^{-6} pc.

Figure 3 and the peak flux (S_L), full width at half power (Δv), and radial velocity with respect to the LSR (v_{LSR}) obtained from a Gaussian fit to the H76α line are given in Table 1. We did not detect the He76α line. However, our upper limit of $He^+/H^+ \lesssim 0.1$ is not very stringent.

Assuming LTE conditions, the electron temperature can be derived from the line-to-continuum ratio:

$$T_e^* = 2.99 \times 10^4 \left[\frac{S_c}{S_L \, \Delta v} \left(\frac{1}{1 + y^+} \right) \right]^{0.87}$$

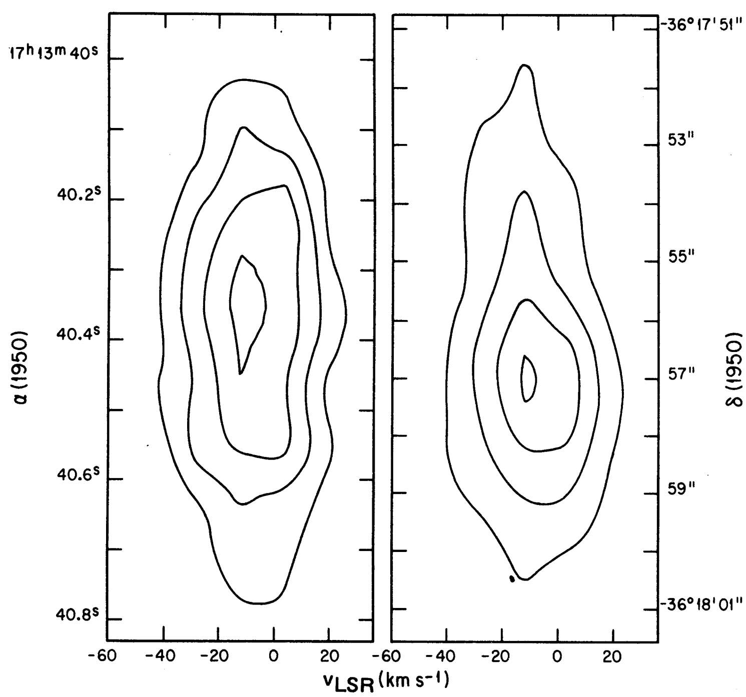

Fig. 5. Radial velocity with respect to the LSR versus right ascension (left) and declination (right) for the H76α emission. The cut in right ascension was made for δ(1950) = $-36^h17^m56\overset{s}{.}8$ and that in declination for α(1950) = $17^h13^m40\overset{s}{.}4$. Contours are 0.3, 0.5, 0.7, and 0.9 of the peak flux of 23 mJy/beam.

Using the parameters given in Table 1 and assuming $y^+ = 0$, we obtain $T_e^* \simeq 7100 \pm 600$ K. However, this determination can be affected by non-LTE departures. Figure 4 shows the T_L/T_L^* ratios for a slab of ionized hydrogen with $T_e = 10^4$ K calculated following Gordon (1971). For an electron density of 3.8×10^4 cm^{-3} and an emission measure of 8.3×10^7 cm^{-6} pc we obtain $T_L/T_L^* = 1.55$ and a corrected electron temperature 1.55 and a corrected electron temperature of 10000 ± 1000 K. This electron temperature and the line width of GM24 are in good agreement with the average value of other ultracompact H II regions (see Table 5 of Garay and Rodríguez 1983).

There is evidence for a gradient in radial velocity across GM24. In Figure 5 we show velocity-position cuts in the E-W and N-S directions across the center of GM24. The N-S cut shows a small gradient of about 6-8 km s^{-1}, with the northern part of the radio source more blueshifted than the southern part. Unfortunately, this velocity shift is about one half of our velocity resolution (16 km s^{-1}) and its presence should be confirmed with observations of higher velocity resolution. Another result that suggests a velocity gradient in the N-S direction is that while the radio core has $v_{LSR} = -10.1 \pm 0.8$ km s^{-1} (Table 1), the optical nebula has $v_{LSR} = -12.3 \pm 1.5$ km s^{-1} (Tapia *et al.* 1985). Again, the evidence is not very strong and additional observations are required.

Since the velocity gradient is small and pressure broadening at the derived densities is negligible, we suggest that the large line width of 42.8 km s^{-1} is probably due to either radial motions (expansion or contraction) or to "turbulence". Most probably we have microturbulent motions similar to those found by Garay, Rodríguez, and van Gorkom (1986) in G34.3+0.2 and G45.07+0.13. Relatively large Doppler widths are characteristically found in ultracompact H II regions (Labrandero *et al.* 1988).

However, the possibility of much larger electron densities as a result of a very thin bowl geometry or considerable clumpiness could invalidate our suggestion. Nevertheless, the HPFW of the Hα line shown by Tapia *et al.* (1985) is about 40 km s^{-1} and seems to corroborate the presence of turbulent motions.

Based on the morphology of the radio continuum, its position with respect to the optical nebulosity, and the evidence for a gradient in the N-S direction, we can conclude that GM24 is a blister H II region undergoing the champagne phase (Yorke, Tenorio-Tagle, and Bodenheimer 1983). An artistic depiction of the region is given in Figure 6.

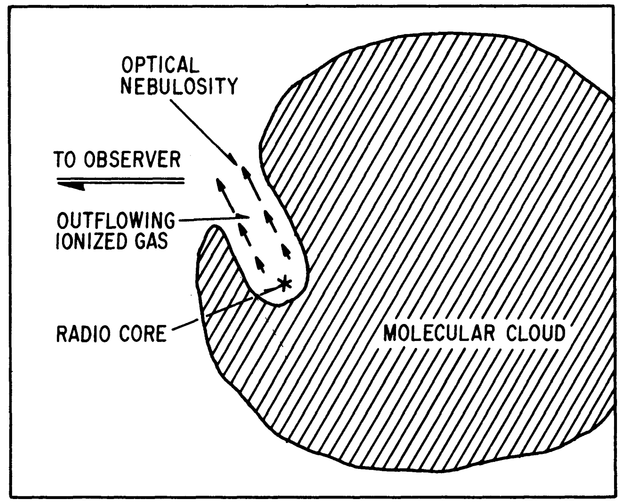

Fig. 6. Artistic depiction of model for GM24. The radio core is embedded in the cloud and not visible in the optical. The H II region has started to burst out of the cloud producing extended emission detectable in the optical. The data shows evidence for a velocity gradient, suggesting that the H II region is in the champagne phase.

IV. CONCLUSIONS

We studied the ultracompact radio H II region associated with GM24 in the H76α line and 2-cm continuum. We derived the nebular parameters. The continuum morphology, its position with respect to the optical nebulosity, and the evidence for a velocity gradient across the face of the H II region suggest that it is a blister H II region undergoing the champagne expansion phase.

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