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OBSERVATIONS OF THE PHOTODISSOCIATED HI REGION THAT SURROUNDS G213.880−11.837

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RESUMEN

Se presentan nuevas observaciones de la línea de HI a 21 cm hacia la región HII cometaria G213.880-11.837. Estas observaciones, llevadas a cabo a una resolución angular de $\sim 15''$, revelan que el gas neutro en esta región es parte de un flujo en expansión. El análisis de la cinemática del gas HI sugiere que este gas está en una etapa de flujo de champagne: esto se basa en la diferencia que hay entre las velocidades radiales del gas neutro en la cola de la región ($\sim$14 km s^{-1}) y la nube molecular ambiente ($\sim$11.5 km s^{-1}) así como en la asimetría del gas de HI en emisión. Además de esta región fotodisociada, solamente hay otra región de este tipo que ha sido reportada presentando un flujo de champagne en HI (G111.61+0.37).

ABSTRACT

New observations of the HI 21 cm line toward the cometary HII region G213.880-11.837 are presented. These observations, carried out with an angular resolution of $\sim 15''$, reveal that the neutral gas in this region is part of an expanding flow. The analysis of the kinematics of the HI gas suggests that the HI gas is undergoing a champagne flow: based on the difference between the radial velocities of the neutral gas in the tail ($\sim$14 km s^{-1}) compared to the velocities of the ambient molecular gas ($\sim$11.5 km s^{-1}) and the asymmetry of the HI emission. Besides this photodissociated region, there is only one other reported following an HI champagne flow (G111.61+0.37).

Key Words: HII regions — radio lines: ISM

1. GENERAL

GGD 14 is a star-forming region, part of the group GGD 12/13/14/15 embedded in the Monoceros molecular cloud at a distance of about 1 kpc (Rodríguez et al. 1980). GGD 14 contains a cluster of radio sources dominated by the compact ($\sim$0.01 pc) cometary HII region (VLA 1; G213.880-11.837), excited by a B0.5 ZAMS star (Rodríguez et al. 1980; Kurtz et al. 1994; Gómez et al. 1998, 2000, 2002) and associated with IRAS 06084-0611. The ionized gas of the cometary HII region is undergoing a champagne flow with the head of the ionized champagne flow located to the NW and the extended emission toward the SE (Gómez et al. 1998). There is a velocity gradient along the major axis of the ionized champagne flow with increasing velocity from $V_{\rm LSR} \simeq 11$ km s^{-1} at the head of the flow to 15 km s^{-1} at the tail. As expected in a champagne flow the velocity at the head is very similar to the velocity of the ambient molecular gas ^{13}CO(2-1) which is $\sim$11.5 km s^{-1}(Qin et al. 2008). In addition of the ionized champagne flow, Gómez et al. (1998) reported the existence of an unresolved photodissociated region (PDR) surrounding the ionized gas.

2. RESULTS

The HI 21 line has been observed with the VLA (Gómez et al. 2010), at an angular resolution of $15''$ and is detected both in absorption and emission in the velocity range from $\sim$1 to 20 km s^{-1} in agreement with previous results reported by Gómez et al. (1998). Figure 1 shows the integrated HI line emission and absorption image superposed on a near-IR continuum image at 4.5 μm from the Spitzer Space Telescope toward GGD 14. Our observations reveal that the size of HI line emission region is about a factor of ten larger than the HII region.

The HI optical depth was estimated using the HI absorption profile toward the HII region: $\tau_L(0) \simeq 5$. Using this result for the optical depth ($\tau_L(0) \gg 1$) the HI column density is estimated to be $N_{\rm HI} \geq 1.1 \times 10^{21}$ cm^{-2}. Further assuming that the physical

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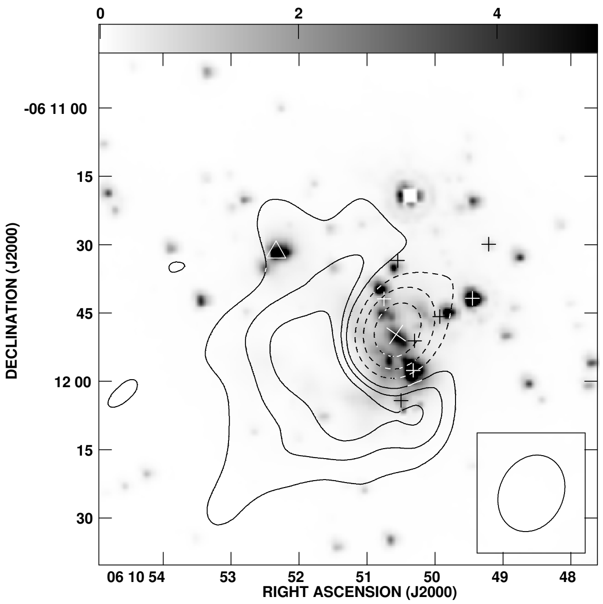

Fig. 1. Near-IR Spitzer image at 4.5 μm (gray scale) superposed on the VLA integrated HI line (from 2 to 20 km s−1) with solid (emission) and dashed (absorption) contours (-20, -10, -3, 3, 6, and 9 $\times$ 0.7 mJy beam^{-1} km s^{-1}). The large 'X' symbol indicates the radio continuum peak position of the HII region and the triangle the peak position of H_2O maser. The crosses mark the peak position of the compact radio sources reported by Gómez et al. (2002).

depth of the region producing the HI absorption is one-half of the diameter of the region with HI emission ($\sim$0.2 pc) an estimate of the average neutral hydrogen density is $n_{HI} \geq 3.5 \times 10^3$ cm^{-3}. Based on this estimation of the neutral hydrogen density it is clear that the compact HII region is embedded in high density atomic gas. Gómez et al. (1998), using observations of the H92α recombination line, interpreted the kinematics of the HII region as a champagne flow.

In order to probe the nature of the morphology for the observed HI gas i.e. verify if it follows a champagne flow, position-velocity diagrams (PV) were made from the HI emission along two perpendicular directions centered on the compact HII region (peak continuum emission). The orientations chosen for the PV diagrams correspond to the orientations of the minor (p.a. $+25°$) and major axes (p.a. $-65°$) of the ionized cometary HII region (Gómez et al. 1998). The HI line in absorption is broad and ranges from 5 to 13 km s^{-1} at the position of the HII region. At this same position the HI emission reaches a maximum velocity of 18 km s^{-1}. Using the value of 11.5 km s^{-1} (Qin et al. 2008) for the velocity of the ambient molecular gas toward GGD 14, we interpret the broad HI line as an indicator of an expanding shell of atomic gas around the HII region, with an expansion velocity of $\sim$6.5 km s^{-1}. The PV diagram along the major axis shows that the HI emission is more extended toward the SE direction than toward the NW if we take as a reference the HII region, reaching velocities in the tail of about 14 km s^{-1}. Given that the molecular ambient gas has a velocity of 11.5 km s^{-1}, the assymetry in the PV diagram along the major axis is interpreted as a champagne flow in the HI gas. This cometary morphology in both the continuum and the HI emission is also observed only toward another HII region: G111.61+0.37, where a champagne interpretation was also proposed (Lebrón et al. 2001).

Dense molecular gas exist in the vicinity of G213.880-11.837 (Qin et al. 2008), where a cluster of low-mass pre-main-sequence stars has been found using radio continuum observations (Gómez et al. 2000). Infrared studies in the $2-100$ μm range (Harvey et al. 1985; Hodapp 1994; Fang & Yao 2004) also provide evidence for a recently formed cluster of sources in the vicinity of G213.880$-$11.837. Estimates of the age for this cluster are in the order of $2-5 \times 10^6$ yr (Fang & Yao 2004). The expansion of the HII region may be triggering the star formation in the molecular cloud which at the same time is responsible of the champagne flow observed in the neutral and the ionized gas toward GGD14.

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