Rev. Mexicana Astron. Astrof., **14**, 506-511 (1987)

HCO^+ AND SO EMISSION ASSOCIATED WITH THE REGION G34.3+0.2

P. Carral, W.J. Welch, and M.C.H. Wright

Radio Astronomy Laboratory
University of California, Berkeley

Resumen. Observamos la region HII G34.3+0.2 en las frequencias 89.1 GHz y 86.1 GHz correspondientes a transiciones rotacionales del HCO^+ y SO. Utilizamos el interferómetro de Hat Creek obteniendo una resolución de $8''.9 \times 6''.3$. La emisión del HCO^+ es extendida, el tamaño aproximado es $\sim 45'' \times 30''$. En contraste, la emisión del SO presenta una estructura compacta aproximadamente del tamaño del haz. La distribución espacial y la velocidad de la nube asociada al HCO^+ favorecen la idea de que la región HII compacta esta en una etapa 'champagne'. En el espectro del HCO^+ se detecta una línea en absorción ancha (~ 20 km s^{-1}) en la posición de la region HII compacta. La absorción observada sugiere la presencia de un objeto joven produciendo un flujo de gas. Una explicación alternativa a las velocidades supersónicas observadas es turbulencia.

Abstract. We have used the Hat Creek millimeter interferometer to map the 89.1 GHz and 86.1 GHz lines of HCO^+ and SO in the direction of the HII region G34.3+0.2. The beam size is $8''.9 \times 6''.3$. The HCO^+ emission shows an extended component $\sim 45'' \times 30''$ in contrast to the SO, that is barely resolved. The spatial distribution and the meassured velocity of the HCO^+ core, support the 'champagne phase' model for the compact HII region. A broad (~ 20 km s^{-1}) HCO^+ absorption is detected towards the compact HII region. This suggests the presence of a young object close to the HII region that is producing an outflow. Turbulence is an alternative explanation for the supersonic velocities observed.

Key Words: NEBULAE-H II REGIONS — RADIO LINES-MOLECULAR — MASERS

I. Introduction

G34.3+0.2 is an HII region complex about 3.8 kpc away and at 40 pc from the supernova remnant W44. High resolution radio continuum observations show one compact (1″) and two ultracompact (0″.3) components within $\simeq 5''$ in projected distance (Garay *et al.* 1986). 20″ south-east of these sources, there is an extended low brightness structure that is clearly seen in the 18 cm map obtained by Reid and Ho (1985). Reid and Ho describe the morphology of the compact HII region making an analogy with comets since it shows a bright "head" followed by a diffuse "tail" that extends westwards. They argue that this peculiar shape is produced by the interaction of the wind from the precursor of the supernova W44, and the molecular cloud associated with the HII region. Garay *et al.* (1986) suggest a different picture in which the HII region is going through a "champagne" phase (Tenorio-Tagle *et al.* 1979). In such a phase, the expansion of the gas into a low density medium can produce the "comet like" appearance and also turbulence that would explain the unusually wide recombination lines observed in this region.

H_2O and OH maser emission centers have been detected towards the compact components. The OH maser emission, that is closely associated with the continuum emission in regions with young massive stars, shows a large (≥ 10 kms^{-1}) redshift with respect to the recombination line. Garay *et al.* (1985) observed the same effect in several compact HII regions, with G34.2+0.2 being one of the extreme cases. They argue that the redshifts can be explained if the masing regions lie in a remnant shell of dense material still falling into the recently formed star.

A molecular cloud associated with this region was mapped by Heaton *et al.* (1985) with 2′.2 and 40″ resolution. They observed the (1,1) and (2,2) inversion transitions of ammonia and found an extended (216″ × 186″) "halo" surrounding a 90″ × 90″ denser "core". Recently, Anderson and Garay (1986) reported high resolution observations of the (3,3) inversion line transition of ammonia. They detected a dense warm core located close to the 'head' component of the HII region and argue in favor of the 'champagne phase' model for G34.3+0.2.

To study the molecular component associated with G34.3+0.2 we made high resolution observations in several rotational molecular transitions using the Hat Creek millimiter interferometer (Carral *et al.* 1986). In this paper we report results for the HCO^+ (1-0) and SO $(2_2 - 1_1)$ transitions.

II. Observations

The observations were made at Hat Creek Observatory, using the three 6.1 m antenna interferometer operated by the University of California at Berkeley. The system works in the range of frequencies 70-115 GHz. For these observations, the local oscillator and correlator were set to observe simultaneously five line frequencies with a spectral resolution of 312 KHz (1.05 km s^{-1} at 89 GHz) and a 20 MHz total coverage at each frequency (67 and 69 km s^{-1} at 89 and 86 GHz respectively). Here we report observations of the 89.1885 GHz and 86.0939 GHz rotational transitions of HCO^+ and SO molecules of the region G34.3+0.2. The phase center of the array was $\alpha(1950) = 18^h\ 50^m\ 46^s.14$ and δ $(1950) = 01^\circ\ 11'\ 12''.5$. The observation periods were december 1985 and june 1986. We observed a total of 7 antenna configurations (21 baselines) obtaining a 8″.9 × 6″.3 beam. The source was observed in 30 min intervals alternating with 9 min integrations on 1749+07 that was used as the instrumental phase calibrator. The antenna gains were determined using Venus as the flux density calibrator, the estimated error in the absolute flux determination is of the order of 20%.

We constructed CLEAN maps using reduction programs developed at Berkeley based on standard methods. For the line maps shown, the continuum was subtracted before cleaning. The noise level in the individual channel maps is 0.7 K in brightness temperature.

III. Results

The HCO^+ spectrum obtained at the position of the HII region is plotted in figure 1. It shows a broad absorption feature against the continuum with a FWZM (full width zero maximum) of ~20 km s^{-1}, and a narrow emission line

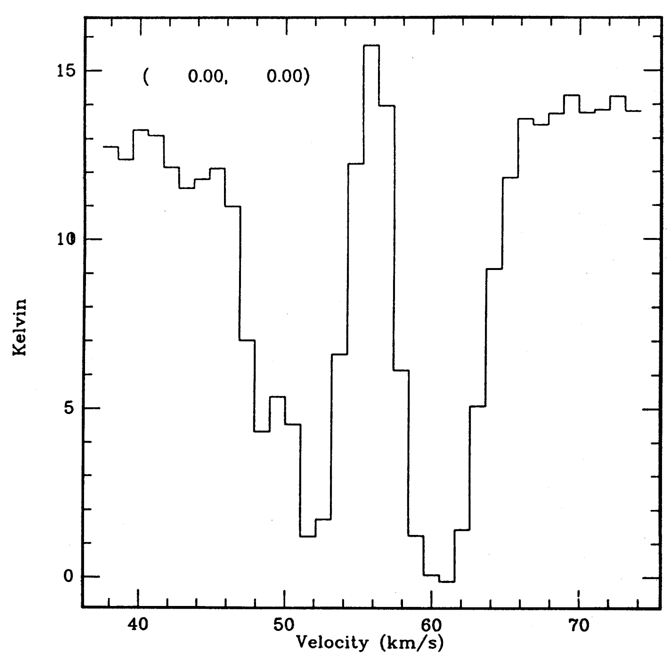

Fig. 1. The HCO^+ spectrum obtained at the position of the compact H II region shows an emission line superimposed to a broad (FWZM ≅ 20 km s^{-1}) absorption feature.

centered at about the same velocity as the absorption profile. The narrow emission component is seen in an extended structure of approximately 45″ × 30″ that corresponds to a linear scale of 0.83×0.55 pc. In figure 2 we present a map of the HCO^+ emission where we have subracted the continuum. Different velocity channels have been averaged to show the global emission but the contour levels are distorted at the central position due to the presence of the absorption. The typical HCO^+ spectra can be fitted with a gaussian function and have a FWHM (full width half maximum) of 3±0.4 km s^{-1}.

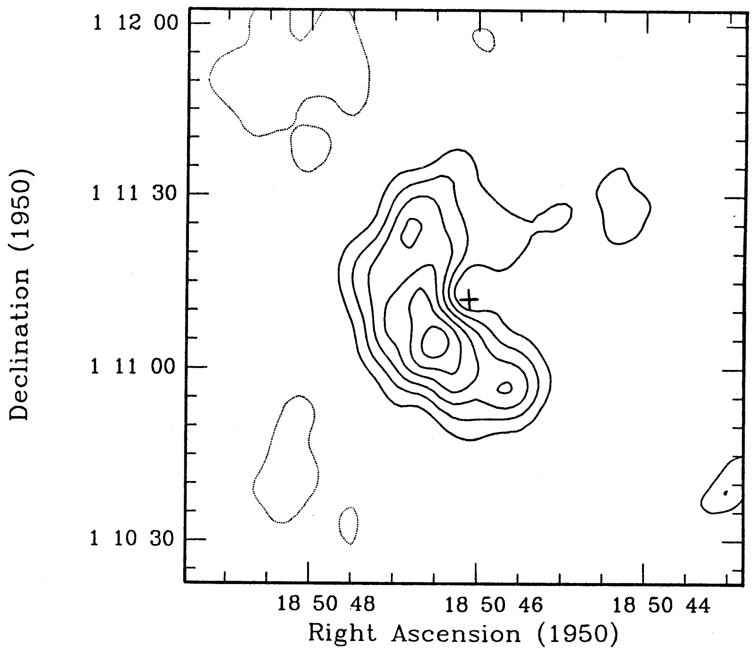

Fig. 2. The map of the HCO^+ emission towards G34.3+0.2 averaged over the velocity range 53 to 59 km s^{-1} shows an extended dense molecular component of approximately 0.83 × 0.55 pc. The position of the compact H II region is shown with a cross mark. The contour interval is 1.5 K.

In figure 3 we show position velocity diagrams centered at the peak of the HCO^+ emission ((−5″, −8″) from the phase center). The diagram in the left is a cut at a 55° angle east of north and goes from NE to SW. The one in the right goes from SE to NW at 145°. From the diagram on the left, an approximately linear velocity structure within the cloud is evident. The measured gradient in the NE-SW direction is 4.6 km s^{-1} pc^{-1}. This will be discused in IV.

The SO emission map, averaged over the line is shown in figure 4. The structure is compact compared to the HCO^+ emission and the position at the maximum is shifted with respect to the position of the compact HII region (marked with a cross in the figure). A gaussian fit to the SO spectrum give a maximum intensity at 57.5 km s^{-1}, and a FWHM of 5.6 km s^{-1}.

IV. Discussion

The size of the molecular core delineated by the HCO^+ is approximately 0.8 X 0.55 pc. Emission is found in a velocity range that goes from 54 to 58 km s^{-1} with a velocity centroid at 56 km s^{-1}. We did not detect emission at the velocity measured for the hydrogen recombination lines associated with the HII region. These are 45.1 km s^{-1} for H66α (Garay *et al.* 1985) and 41.1 km s^{-1} for H76α (Garay *et al.* 1986). Unless the emission at these velocities has been autoabsorbed, the cloud associated with the HII region has a velocity of 56 km s^{-1}; the shift between the ionized gas and the molecular material is then ≥10 km s^{-1}. In the ammonia observations by Heaton *et al.* (1985) they quote a velocity of 59 km s^{-1} for the molecular cloud.

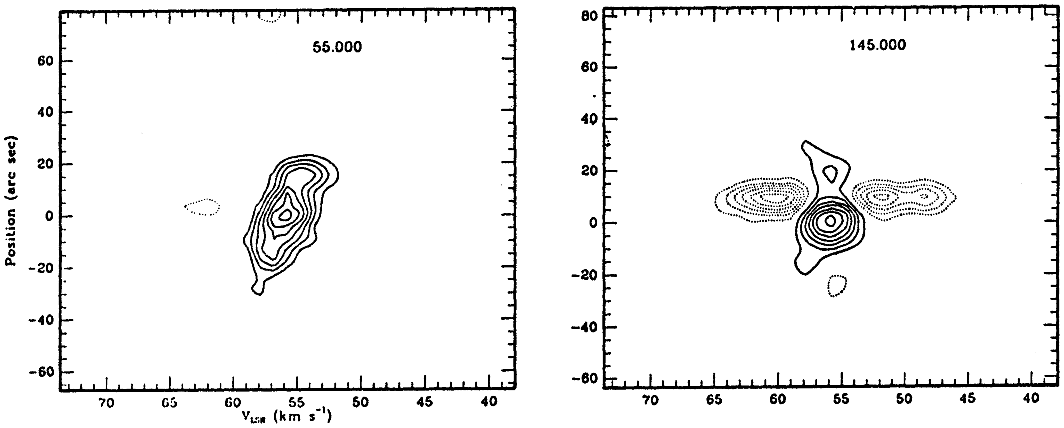

Fig. 3. The figure shows velocity position diagrams centered at the position of the maximum in the HCO^+ emission. The one in the left is a cut at a 55° angle, going from NE to SW. The diagram in the right is a cut at 145° going from SE to NW. The contour levels are 2.0 K.

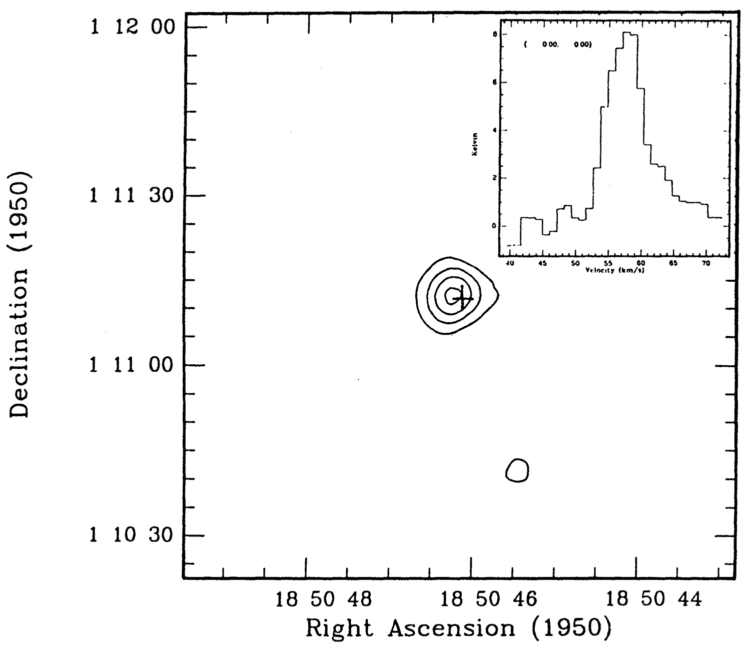

Fig. 4. The map of the 86.1 Ghz SO emission towards G34.3+0.2 averaged over th velocity range 53 to 60 km s^{-1} shows a compact component roughly coincident with the H II region (indicated with a cross mark). The contour interval is 1.5 K. The SO spectra, at the top right of the figure has a central velocity of 57.5 km s^{-1} and a FWHM of 5.6 km s^{-1}.

The velocity centroid measured for the OH masers is 58.2 km s^{-1} (Garay *et al.* 1985), the similarity with the observed cloud velocity indicates that the masing regions are probably embedded within the cloud. The suggestion by Garay *et al.* (1985) that the velocity difference detected between the OH masers and the recombination lines locates the masing spots within a remnant shell of dense material still falling into the newly formed HII region is ruled out in this particular region by the fact that the cloud traced by the HCO^+ has essentially the same velocity as the maser spots. Heaton *et al.* (1985) came to the same conclusion.

The blueshift observed in the recombination lines, that corresponds to a velocity difference greater than 10 $km\,s^{-1}$ with respect to the cloud , still has to be explained. The 'champagne phase' model, suggested by Garay *et al.* 1985 to explain the width in the recombination lines, and invoked by Andersson and Garay (1986) to produce the redshift in the OH masers velocities relative to the HII region seems very appealing. In the calculations by Tenorio-Tagle *et al.* (1979) the ionized gas can reach velocities as high as 30 $km\,s^{-1}$, projected velocities of 10 to 15 $km\,s^{-1}$ seem to be possible to obtain. The distribution of the detected molecular gas is not symmetric with respect to the HII region, it lies preferentially between the compact and the extended structure seen at 18 cm (Reid and Ho 1985). This favors the 'champagne phase' model and suggests an interaction of the HCO^+ core with the continuum extended structure.

From figure 3, we derive a velocity gradient of 4.6 $km\,s^{-1}\,pc^{-1}$ for the molecular cloud with the velocity increasing from SW to NE. The origin of the velocity gradient is not clear. If it is due to rigid body rotation the required mass to balance the centrifugal force can be estimated considering the most exterior orbit that correspond to the greastest speed. Taking a radius of 0.41 pc and a circular velocity of 1.9 $km\,s^{-1}$ the corresponding mass is 350 $M_\odot$, there are ~30% variations on this value depending on the precise position of the rotation angle that is not well defined.

From the ammonia observations, Heaton *et al.* (1985) derive a hydrogen density of $3.7 \times 10^4\,cm^{-3}$ for the large scale distributed molecular gas. If we assume the same density in the HCO^+ 'core' the estimated mass is also of the order of 350 $M_\odot$ with uncertainties depending on the specific cloud shape assumed in the calculation. For a core of this mass, the assumed rigid body rotation would be dynamically important in supporting the cloud from collapse, but the estimated mass is probably a lower limit. The HCO^+ critical density can be as high as 10^6 cm^{-3} depending on the temperature of the region, and even a density of 10^5 cm^{-3} can more than double the estimated value. It appears from these rough estimations, that the observed velocity gradient, if it is due to rotation , would not be enough to equilibrate gravity in this HCO^+ core.

In contrast with the HCO^+ distribution, the SO map (figure 4) shows a much more compact structure, the emission is barely resolved in the SW-NE direction with an approximate size of 8″; in the SE-NW direction the beam is wider so the estimation of the source size is not accurate but is possible to say that the SO emission is not as extended in this direction as it is in the SW-NE, the emission comes from an elongated structure. In this case, there is not a velocity gradient evident from the maps or spectra.

In other star forming regions, the observed SO emission also shows a compact structure and it has been found to be closely related with outflows. Based on these observations, Welch *et al.* (1986) have suggested that the SO abundance is enhanced in these regions where shocks are present. In G34.3+0.2, the SO emission may be tracing a shock and an outflow as it does in other star forming regions. The broad absorption observed in the HCO^+ profile may be independent evidence for the presence of such an outflow.

As we see in figure 1, the continuum emission is completely absorbed at a velocity of 61 $km\,s^{-1}$ indicating that the foreground HCO^+ gas is optically thick. The fact that we see the HCO^+ emission line at velocities near 58 km s^{-1} without indications of absorption shows that the absorbing material cannot be uniformly distributed in front of the emitting gas, since the lines would be absorbed. One possible alternative to solve this problem is to argue that the filling factor of the absorbing material is less than one as it would be the case of a clumpy medium. The problem is then to adjust the clump parameters in such a way that the clumps cover completely the HII region and not the observed molecular cloud. The alternative location for the absorbing material is 'between' the HII region and the HCO^+ emission core.

The absorption line has a full width zero maximum of approximately 20 $km\,s^{-1}$ indicating highly supersonic gas motions, the fact that the absorption is blue and redshifted with respect to the cloud velocity can be explained either by turbulence or by bulk gas motion. Unless the chaotic expansion of the HII region is inducing such a turbulence, it is possible to argue the presence of a young object in front to the HII region that is producing an outflow detected as an absorption in the HCO^+ profile.

V. Conclusions

We mapped the HCO^+ and SO emission associated with the HII complex G34.3+0.2 with an angular resolution of $8''.9 \times 6''.3$.

1. The HCO^+ emission is extended, with an approximate size of 0.83×0.55 pc. Single dish observations will help to know how much flux we are resolving out. There is evidence for velocity structure within the HCO^+ core, a velocity gradient of 4.6 km s^{-1} pc^{-1} was meassured at an angle of 55° east of north. The spatial distribution of the HCO^+ and the measured cloud velocity, favor the 'champagne phase' model proposed for the compact region.

2. As in other star forming regions, the SO emission shows a compact structure ($\leq 8''$). There is not clear evidence of a velocity gradient in the SO component. The compact SO emission may be tracing shocks ocurring in the region. Higher resolution observations, which are in progress, will resolve the source and clarify the spatial and velocity distribution of the SO emitting material.

3. The HCO^+ profile shows a broad ($\sim$ 20 km s^{-1} FWZM) absorption feature against the continuum emission from the compact HII region. The high optical depth of the HCO^+ absorbing gas, locates this gas spatially, 'between' the compact HII region, and the HCO^+ emitting core. If this is correct, then the broad absorption is related to highly supersonic turbulence, probably produced by the HII region, or to an outflow from a young object located close to the compact region.

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P. Carral, W.J. Welch, M.C.H. Wright : Radio Astronomy Laboratory , University of California, Berkeley, CA, 94720, U.S.A.