The atomic hydrogen/molecular cloud association : an unavoidable relationship

G. JONCAS
Dept. de Physique
Université Laval
and Observatoire Astronomique du mont Mégantic
Québec, Québec
Canada G1K 7P4

1. INTRODUCTION

The presence of HI in the interstellar medium is ubiquitous. HI is the principal actor in the majority of the physical processes at work in our Galaxy. Restricting ourselves to the topics of this symposium, atomic hydrogen is involved with the formation of molecular clouds and is one of the byproducts of their destruction by young stars. HI has different roles during a molecular cloud's life. I will discuss here a case of coexisting HI and H_2 at large scale and the origin of HI in star forming regions. For completeness' sake, it should be mentionned that there are at least three other aspects of HI involvement : HI envelopes around molecular clouds, the impact of SNRs (see work on IC 443), and the role of HI in quiescent dark clouds (see van der Werf's work).

2. HIGH RESOLUTION OBSERVATIONS OF A HIGH LATITUDE GAS COMPLEX

This study was prompted by the IRAS discovery of large filamentary structures baptized cirrus. These have been correlated with local interstellar clouds, either atomic or molecular. Joncas, Boulanger and Dewdney (1990, in preparation) undertook the HI line study of such a cloud in order to understand their kinematical behaviour and density structure. The observations were obtained with the aperture synthesis radio telescope of the Dominion Radio Astrophysical Observatory (DRAO). The data set was completed by filling the inner portion of the uv planes with single dish observations. The resolution (FWHM) was 1'.0 x 1'.06 x 0.66 km s^{-1}. The results will be used to make comparisons with the structure of molecular clouds to get a better understanding of the transformation from one kind of cloud to the other.

The area we chose is part of a 21° x 12° (l x b) loop of atomic gas called the North Celestial Pole loop. This object is a complex of molecular and atomic clouds as demonstrated by de Vries et al. (1987) in a 9' (HPBW) survey of an 8° x 8° section of the loop. Our observations cover the section having the brightest HI emission. We resolved the HI feature into several filaments and clumps having different radial velocities. Emission was

E. Falgarone et al. (eds.), Fragmentation of Molecular Clouds and Star Formation, 37–40.

detected in the 14.21 to -3.1 km s^{-1} velocity range. Figure 1 is a gray scale representation of one of the velocity maps. The feature's morphology is truly amazing, showing criss-crossing filaments and clumps of all sizes. Examination of the HI spectra reveals complicated multi-component profiles with FWHM varying between 1 and 3 km s^{-1}. Assuming optically thin conditions and uncertain geometries, densities smaller than 100 cm^{-3} are derived. Using these quantities and the strength of the local magnetic field (Heiles 1989), it appears that the magnetic pressure dominates the forces at work on this HI cloud. The magnetic field may thus secure the coherence of the cloud's substructures. We know from de Vries et al.'s work that the HI and CO clouds are closely linked. One may now ask wether the HI feature originates from the dissociation of the nearby molecular cloud or if a molecular cloud is now forming after the crossing of the shock front that created the loop. The quiescence of the molecular cloud and the location of the features in the loop argue against a shock front presently crossing the cloud. So far our HI observations and CO observations of others indicate that both clouds are not in equilibrium. Since they are small entities (7.5 pc. if located at 100 pc. as proposed by de Vries 1987), they may represent a very early stage of molecular cloud formation.

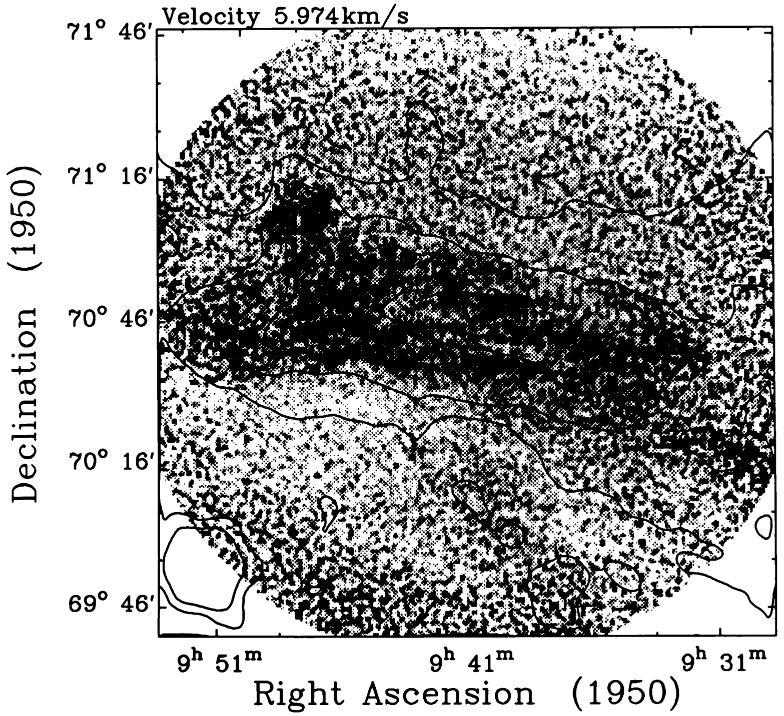


Figure 1. Map of HI line emission over a 2° field of view. There are 11 gray scale levels starting at 5 K with steps of 2.5 K. The overlaid contours are 100 μm emission at 2, 4, and 6 MJy/sr.

https://doi.org/10.1017/S0074180900198754 Published online by Cambridge University Press

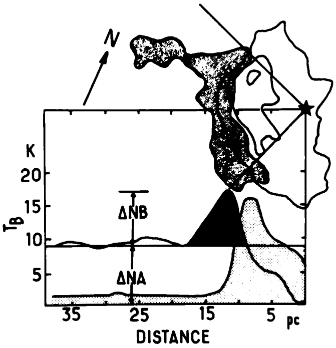
3. DISSOCIATED HYDROGEN

This section is a short summary of an ongoing project consisting on the study of HI associated with HII region/molecular cloud complexes. Such an association can be expected since newly formed massive stars produce substantial amounts of UV photons longward of the Lyman limit. Their absorption by the hydrogen molecule will produce its dissociation. Hill and Hollenbach (1978) proposed such a scenario where an H_2 dissociating front precedes the ionization front (IF) into the molecular cloud producing a layer of atomic gas. The HII region could dynamically affect this interface. Indeed the IF may have a shock front preceding it, advancing through the atomic layer. This interface, also called a photodissociation region, is important to a molecular cloud specialist, it is a source of information about the physics, chemistry and structure of molecular clouds not forgetting its impact on star formation. Read (1981, and references therein), using aperture synthesis, studied the kinematical behaviour of the HI component of 3 star forming complexes. His results brought the first strong qualitative evidence for the presence of dissociated hydrogen. This kind of work was quantitatively continued by Dewdney and Roger at DRAO (Roger and Dewdney 1986 and references therein).

One of the proofs for the existence of dissociated hydrogen came from a study of the S142 complex (Joncas et al. 1985). On the eastern side of the nebula is an HI feature ($\approx$1200 M_o) whose west side contours follow the slope and curvature of those on the radio continuum quite accurately. The LSR velocity of the feature is identical to that of the CO cloud. Figure 2 is a plot showing a radial profile of continuum and HI emission, both averages over a 90° sector centered on the exciting star. Noteworthy is the local minimum of HI emission near the star and the fall off of the continuum emission as the HI emission rises up. The characteristics (mass and thickness) of the HI ridge are reproduced by the Dewdney-Roger (DR) model.

Another good example is the S187 complex (Joncas et al. 1990 in preparation). S187 is a textbook example of a young photodissociation zone. The HII region is surrounded by a clumpy HI shell. Its mean thickness is 1.1 pc and its total mass is 60 M_o. Applying the DR model such an amount of HI is produced in $\approx 10^5$ years using an observed density of 10^4 cm^{-3} for the molecular cloud. Theoretically the dissociation front is now 0.6 pc away from the exciting star. Close to the observed value of 0.9 pc (half intensity of the shell) for the eastern side. The mean velocity of the shell (-16.2 km s^{-1}) is somewhat blueshifted with respect to the velocity of the molecular cloud (-15 km s^{-1}). To better understand the behaviour of the HI shell, multi-molecule observations (^{12}CO, ^{13}CO, $C^{18}O$, CS) of the shell area were secured using the FCRAO 14 m antenna. Figure 3 is a ^{13}CO antenna temperature contour map of a 16' field centered on the HII region. The full line circle represents the extent of the ionized gas while the dashed line depicts the outer boundary of the HI shell. Both seem to sit in a molecular hole, confirming the eroding action of the exciting star. Also noticeable is the presence of the CO core depriving the HI shell of its sphericity. In fact the shell is twice as thin on its eastern side evidently because the dissociating photons have a harder time penetrating the denser material (more dust absorption).

https://doi.org/10.1017/S0074180900198754 Published online by Cambridge University Press



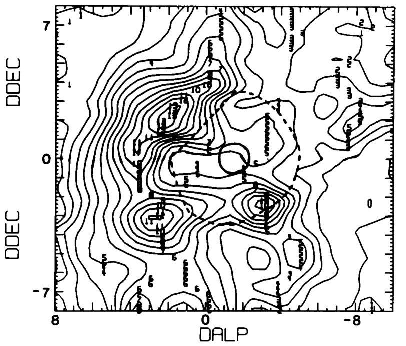


Figure 2 (left) Radial profiles of radio continuum brightness temperature (lower) and HI column density (upper) from S142. They are shown relative to the continuum emission (contours) and adjacent HI emission (shaded contour).

Figure 3 (right) ^{13}CO antenna temperature (T_A*) contour map of a section of the S187 molecular cloud. The full circle and dashed line circumscribe the HII region and the HI shell respectively.

Also apparent in Figure 3 is the presence of 3 major condensations. The northern one (the core) does not appear in our CS map but does so in $C^{18}O$. The southeastern one has a strong CS and $C^{18}O$ counterpart. This can be explained if the core is heated by the star forming activity (the HI shell seems in contact with it). The latter component is denser but not colder and does not seem in contact with the HI shell, it contains however a bipolar outflow. The data have not been completely analyzed yet. One of the goals is the comparison of the kinematical activity of the shell against the molecular cloud's. As mentioned previously the HI shell should be made up, at least in part, of shocked gas. However shock fronts of this type have never been observed. One possible reason for this is that the pressure transition usually thought to exist at an IF which would give rise to a shock is not present because of substantial heating of the atomic gas in advance of the front. If this is the case the HI gas will be expanding away from the molecular cloud.

To conclude I will emphasize further the importance of such studies by mentioning the discovery of a dissociating star by Dewdney et al. : a B4 star having a very small HII region (6.6 x 10^{-4} M_o) but a large amount of atomic gas surrounding it (1.4 M_o). HI observations could thus become tracers of B stars in molecular clouds.

de Vries, H. W., Heithausen, A., and Thaddeus, P. 1987, Ap. J. 319, 723.
Heiles, C. 1989, Ap. J.336, 808.
Hill, J. K. and Hollenbach, D. J. 1978, Ap. J. 225, 390.
Joncas, G., Dewdney, P.E., Higgs, L. A., and Roy, J.-R. 1985, Ap. J. 298, 596.
Read, P. L. 1981, M.N.R.A.S., 195, 371.
Roger, R. S. and Dewdney, P. E. 1986, in IAU symposium 115, Star Forming Regions, ed. M. Peimbert and N. Kaifu, (Dordrecht:Reidel), P. 203.

https://doi.org/10.1017/S0074180900198754 Published online by Cambridge University Press