Aromatic emission bands from the HII region ahead the Horsehead Nebula

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ABSTRACT

We present a study of Aromatic Infrared Band (AIBs) emission in the IC434 HII region ahead the Horsehead nebula as well as in the associated photodissociation region (PDR). AIBs are detected in the HII region and the correlation of the 11.3 μm AIB with ionised gas lines shows that PAHs must be located in the ionised gas. The survival of AIBs emitters in the HII region could be due to the moderate intensity of the radiation field ($G_0 \sim 100$) and the lack of photons with energy above ~ 25 eV. The relatively high strength of the 11.3 μm AIB regarding the other AIBs at 6.2, 7.7 and 8.6 μm in the HII region spectrum is explained by the presence of neutral PAHs in the ionised gas while they are mostly ionised in the PDR. Our observations highlight a transition region between ionised and neutral PAHs observed with ideal conditions in our Galaxy. A scenario where PAHs can survive in HII regions and be preferantially neutral could explain the detection of a prominent 11.3 μm band in other Spitzer observations.

Subject headings: galaxies: ISM — infrared: galaxies — infrared: ISM — ISM: dust, extinction — ISM: HII region — ISM: lines and bands

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1. Introduction

Aromatic Infrared Bands (AIBs) have been detected in a wide range of interstellar conditions (e.g. Boulanger et al. 1998). These bands have already been reported in spectra of HII regions but never with clear proof that their emitters are located within the ionised gas rather than in the associated photodissociation region (PDR) (e.g. Peeters et al. 2002). Moreover, several studies report the destruction of PAHs in highly excited HII regions which is attributed to the strong radiation field (e.g. Kassis et al. 2006). The presence of PAHs in HII regions can have a noteworthy impact on their energetic balance through photoelectric heating (e.g. Weingartner & Draine 2001). In this paper, we report the detection of AIBs in the HII region spectrum ahead the Horsehead Nebula and study the survival and the physical properties of PAHs in this environment.

Both the IC434 HII region and the Horsehead nebula are excited by σOri O9.5V binary system. The UV intensity of the radiation field is $G_0 \sim 100$ (energy density of the radiation field between 6 and 13.6 eV in unit of Habing field, Habing 1968) at the Horsehead nebula location (3.5pc from the star). The edge-on geometry of this object allows us to observed separately the HII region and the PDR.

The Horsehead has been observed in spectral mapping mode using IRS/Spitzer as part of the SPECPDR program (Joblin et al. 2005). Data which are used in this paper are related to the computed spectral cube (two spatial dimensions and one spectral dimension) from the Short-Low and Long-Low BCD data, except for the Hα emission which was observed by Pound et al. (2003). For the complete study as well as for details of data reduction, see Compiègne et al. (2007).

2. PAHs survival in the HII region

As shown on Fig. 1, the 11.3 μm AIB intensity is correlated to those of [NeII]12.7 μm and Hα (data from Pound et al. 2003) in the HII region. The HII region is defined by fixing a lower limit on the $I_{H\alpha}$ and an upper limit on I(H_2 0-0 S(2) at 12.3 μm) to avoid PDR emission. The corresponding area is shown by the contour the most to the west on maps of Fig. 2. We conclude from the two correlations of Fig. 1 that PAHs are located within the ionised gas.

In the HII region, we detect ionised species with ionisation potential (IP) lower or equal to those of [SIII] (IP = 23.34 eV) and not the one with IP equal or higher than that of [ArIII] (IP = 27.63 eV). We conclude that PAHs must survived in the ionised gas where the radiation field has an UV intensity of $G_0 \sim 100$ and which does not contain photons with energy greater than ∼25 eV. Note that the presence of PAHs in the ionised gas could be related to the photoevaporation of the dense ridge which continuously brought "fresh" matter in the HII region.

3. Physical properties of PAHs

As shown on Fig. 2, the intensity of the 6.2, 7.7 (C-C stretching mode) and 8.6 μm (C-H bending mode) bands relatively to the intensity of the 11.3 μm band (C-H mode) is $\sim$2-3 times larger in the inner region (PDR) spectrum than in the HII region spectrum. Rather than size or hydrogenation state variations, a variation of the PAHs charge state between the HII region and inner region (PDR) is the most straightforward explanation for this band ratio variation.

The charge state of PAHs is mainly determined by the balance between photoelectric effect and electronic recombination which must have different efficiencies in these two regions. The inner region (PDR) band ratio can be interpreted by the presence of cationic PAHs which is coherent with the presence of UV photons (enhanced photoelectric effect) and the lack of free electrons (low recombination rate). In the HII region, we use CLOUDY (Ferland et al. 1998) in order to compute the charge state of PAHs in a fully ionised medium illuminated by an O9.5V star located at 3.5 pc from a cloud. We take $T_{gas} = 7500$ K and $n_e \sim 100 - 350\,cm^{-3}$ (computed using the [SIII]19 and 33 μm lines ratio). For PAHs with radius from 4.5 to 10.5 Å and distributed as $n(a) \propto a^{-3.5}$ (Bakes & Tielens 1994), we obtain a mean charge of 0.55-0.75 electron per PAH. Thus, the HII region spectrum must be emitted

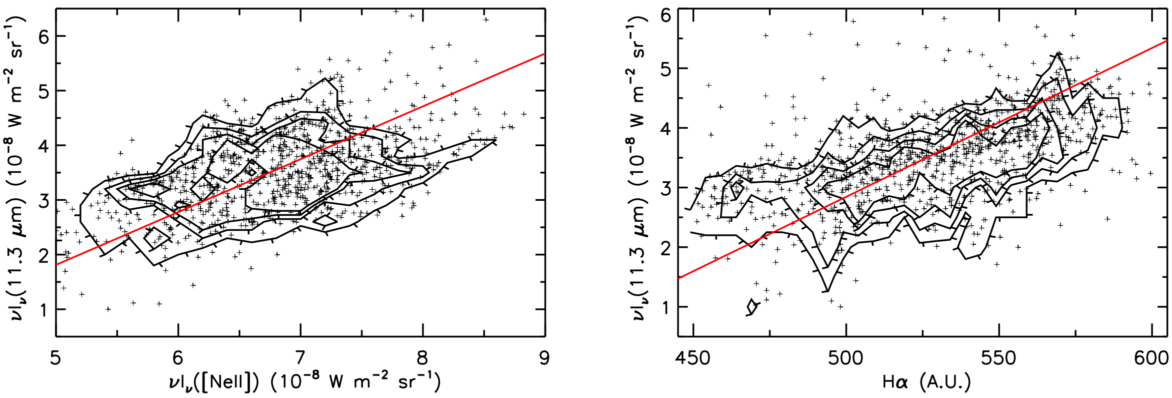

Fig. 1.— Relationship between intensities of [NeII]12.7 μm, Hα (data from Pound et al. 2003) and 11.3 μm for pixels of the HII region (as defined on sect. 2, see contours on Fig. 2). Contours are histograms of point densities. The red straight lines are linear fits to the data.

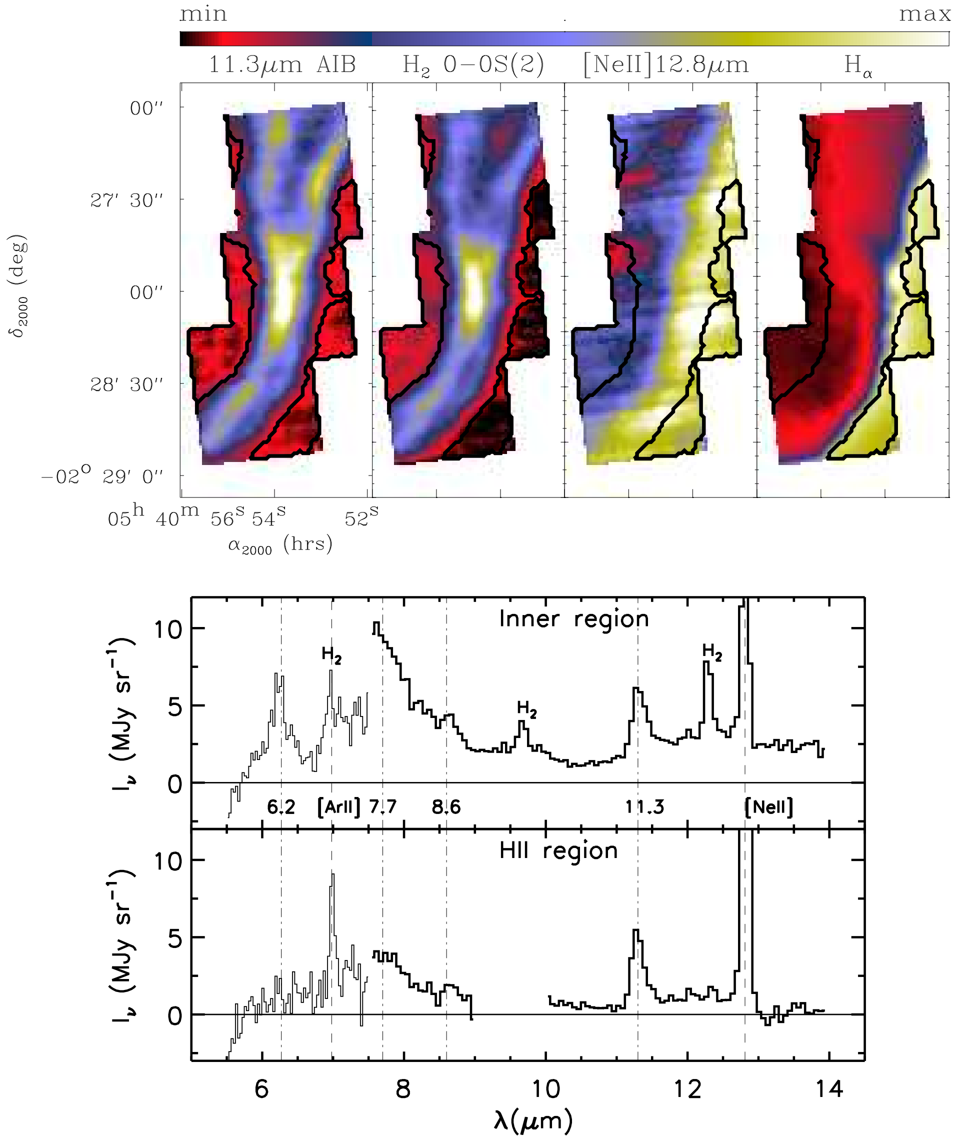

Fig. 2.— **Maps:** Emission maps of 11.3 μm AIB, H_2 0-0 S(2), [NeII]12.8 μm and Hα. On each map, the two contours show the area of the HII region (West of the H_2 emission peak) and of the inner region (PDR, East of the H_2 emission peak). Note that the illuminating star (σOri, type O9.5V) is located $\sim$0.5° to the West of the Horsehead. **Spectra:** Mean spectra of the HII region and of the inner region (PDR). [NeII]12.8 μm has been truncated for simplicity. Zodiacal emission has been subtracted. The 9-10 μm part of the HII region spectrum has been suppressed since it contains an artefact.

by a mixture of neutral and anionic PAHs.

4. Summary

AIBs are clearly detected in the HII region ahead the Horsehead nebula. The intensity of the 11.3 μm AIB is correlated with those of the ionised gas species. Moreover, we see a spectral variation of the AIB spectrum which is clearly correlated with variations of physical conditions between the HII region and inner region (PDR). Thus, PAHs must survived in the ionised gas ahead the Horsehead nebula. We also conclude that a radiation field with an intensity of $G_0 \sim 100$ and without photons of energy above $\sim$25 eV is not able to efficiently destroy PAHs. Lebouteiller et al. (2007) reached similar results in the NGC3603 giant HII region. We show that the shape of the AIBs spectrum in the HII region can be explained by the presence of neutral PAHs. This result highlights the transition of PAH properties between neutral gas and highly excited HII regions in the ideal conditions of the Horsehead nebula and allows us to derive a physical scenario in order to interpret spectra of more intricated or extragalactic sources.

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