PDR-Produced HI in GMCs of M33 - a comparison of high and low resolution data

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ABSTRACT

We report our latest findings on the volume densities of molecular hydrogen in Giant Molecular Clouds (GMCs) associated with photodissociation regions (PDRs) in the nearby galaxy M33 (the Triangulum galaxy), using HI continuum, FUV- and metallicity data.

The morphology of the atomic hydrogen distribution is similar to what is expected for PDRs, since the HI is seen surrounding bright FUV sources. Potential PDRs that we detect, in which dissociating photons dominate the radiation field, have sizes in the order of 100 parsec. Complexes of young, hot stars are responsible for these PDRs. They create a 'blanket' of photodissociated HI. This HI can be converted into H_2 again, recycling the atomic gas.

Verification of the PDR scheme that we are testing depends ciritically on the spatial resolution of the M33 data. To this end we investigated potential PDRs of M33 both at a resolution of about 100 parsec as well as 30 parsec, using new high resolution M33 radio data kindly provided by David Thilker and Robert Braun. We also used publicly available Galex UV data at a comparable resolution. Earlier results for M81 (Heiner et al., 2008) and M83 (Heiner et al., in prep.) had the right resolution to apply our method, but lacked the spatial resolution to truly discern any structure.

We analyzed HII region BCLMP 0288 and find that lower resolution analysis would overestimate the total hydrogen volume density. The value we find at the full resolution is 5 cm^{-3}.

Subject headings: galaxies: ISM — ISM: structure — galaxies: individual: M33 — ISM: clouds

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1. Introduction

Photodissociation regions (PDRs) near star forming regions (SFRs) harbor a complex chemistry. They facilitate not only the conversion of atomic hydrogen into molecular hydrogen, but also the reverse process. As such, they are producers of atomic hydrogen. This property is used here to deduce the underlying total hydrogen density.

Every FUV source is surrounded by patches of HI. The distances to these patches are determined using a spherical model, PA and i corrected.

HI column density, dust-to-gas ratio δ/δ_0 and incident FUV flux G_0 are connected to the total hydrogen volume density. The dust catalyzes the formation of H_2 and attenuates the FUV radiation.

$$N_{HI} = \frac{7.8 \times 10^{20}}{\delta/\delta_0} \ln \left[1 + \frac{106 G_0}{n_H} (\delta/\delta_0)^{-1/2} \right] \text{ cm}^{-2} \quad (1)$$

2. Results

Figure 1 shows a fragment of the north-western part of M33 is shown at full resolution ($\tilde{5}''$). Red indicates HI emission, green is Far-Ultraviolet emission. Both are scaled to emphasize the structure of the atomic gas and the distribution of FUV sources. A general picture of FUV sources embedded in HI gas emerges. These FUV sources are our candidate PDRs. In Figure 2 we zoom in to such a region, called BCLMP 0288 (Boulesteix et al., 1974). This area is a prime example of a giant HII region with O and B stars clustered at the center. Its scale is of the order of a few hundred parsec. A depression in the atomic hydrogen column density coincides with the UV emission. The HI distribution looks like a shell, particularly in the lower-left side. This feature is also clearly visible in the smoothed and decimated lower resolution version (30″), which is Figure 3. Here we display the HI in grayscale and the FUV emission as contours. The dashed red line indicates the location of an HI shell. The central cluster of stars is unresolved. Both resolutions are plotted, because we aim to get a better idea of the resolution effects and biases that occur when galaxies are observed at larger distances. The resolution of 30″ was chosen to match a linear resolution comparable to M81 data we used in Heiner et al., 2008.

At 30″ resolution, the FUV source has a flux of $F_{FUV} = 3.9 \times 10^{-14}$ ergs cm^{-2} Å^{-1}. The maximum HI column density along the dashed red line is $N_{HI} = 2.0 \times 10^{21}$ cm^{-2}. The resulting total hydrogen volume density (at a dust-to-gas ratio of 0.32, Crockett et al., 2006) is $n = 50$ cm^{-3}.

At 5 $''$ resolution, $F_{FUV} = 1.8 \times 10^{-14}$ ergs cm^{-2} Å^{-1}. This value is the sum of the 4 central resolved sources (each still a cluster of an unknown number of O and B stars). $N_{HI} = 5.4 \times 10^{21}$ cm^{-2}, the average column density along the HI shell. In this case an average is more appropriate since the signal-to-noise level is poorer than in the smoothed image. $n = 5$ cm^{-3}, at the same dust-to-gas ratio.

The full resolution FUV flux is somewhat lower than the one determined from the smoothed data, because the sources further removed from the central source were resolved and not included. The HI column turns out to be higher, despite taking the average column instead of the local maximum. In this case, analyzing the lower resolution data means overestimating the total hydrogen volume density by up to a factor of 10.

3. Summary

We analyzed the HII region BCLMP 0288 and determined a total hydrogen volume density of 5 cm^{-3} at the full available resolution. The morphology is consistent with the HI being recycled atomic gas. A lower resolution analysis would overestimate the total volume density in this case. More regions are expected to be analyzed, in an effort to get more insight into the bias of previous published work (Heiner et al., 2008). Detailed comparisons with molecular hydrogen abundance estimates from CO data are also anticipated.

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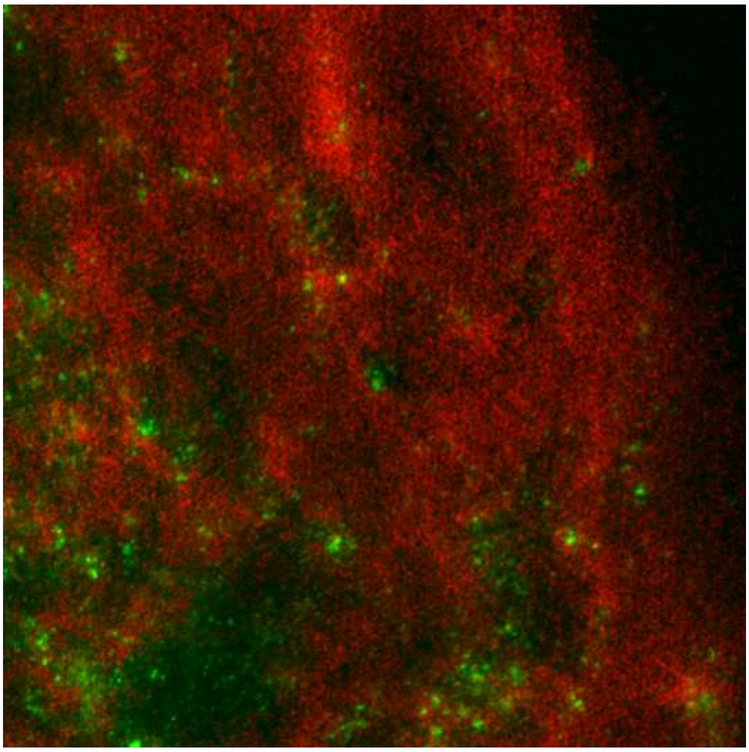

Fig. 1.— North-western part of M33 at full resolution. The atomic hydrogen is colored red, the central UV source is colored green.

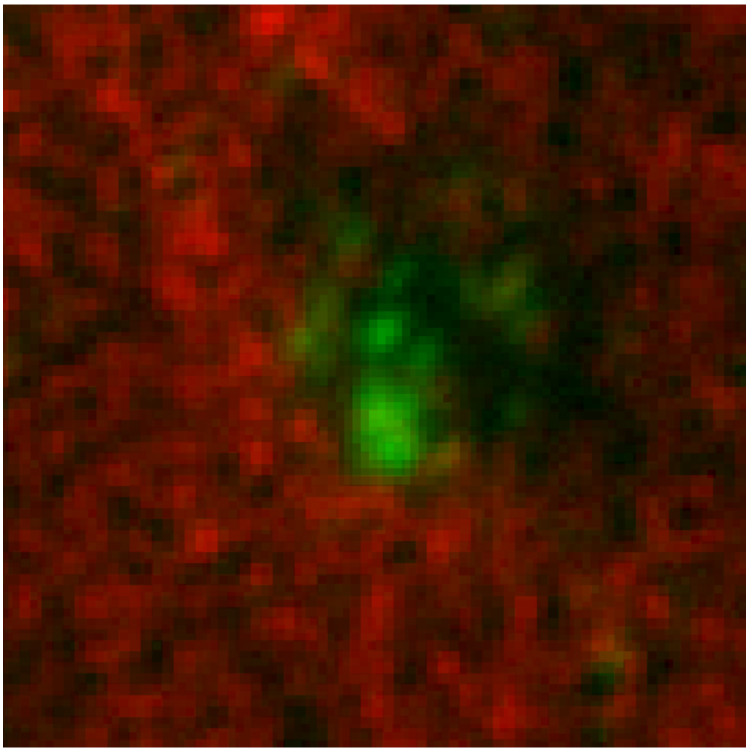

Fig. 2.— BCLMP 0288 (Boulesteix et al., 1974) at 5″resolution. The atomic hydrogen is colored red, the central UV source (resolved) is colored green.

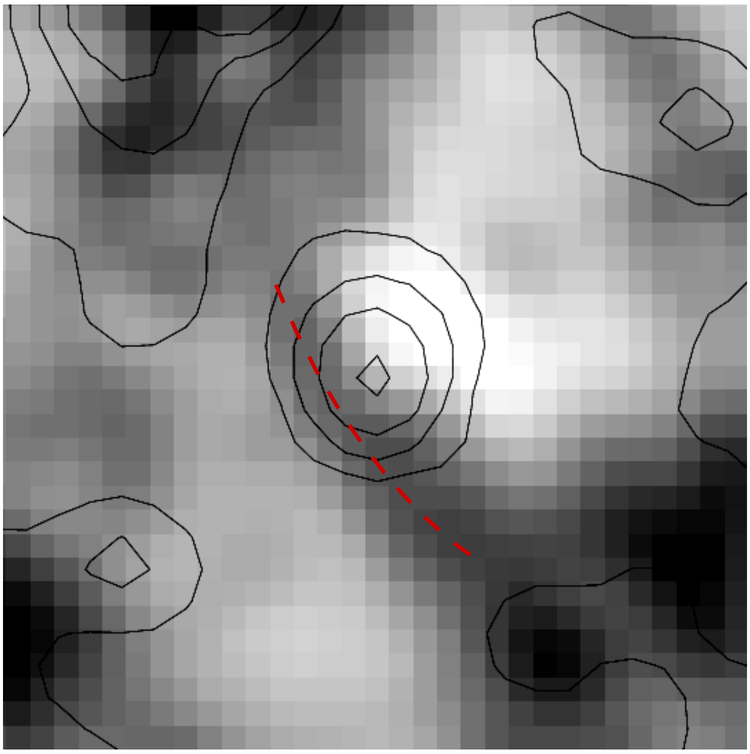

Fig. 3.— 30″HI grayscale and FUV contours. The central source is unresolved. The dashed red line follows the HI shell.