Molecular gas and star formation in M81

V. Casasola 1, 2, F. Combes 2, G. Galletta 1, and D. Bettoni 3

1 Università di Padova, 2 Observatoire de Paris-LERMA, 3 INAF-Osservatorio di Padova

Abstract. We present IRAM 30m observations of the central ~1.6 kpc of the spiral M81 galaxy. The molecular gas appears weak and with an unusual excitation physics. We discuss a possible link between low CO emission and weak FUV surface brightness.

1. Introduction

The M81 galaxy, studied at all wavelengths, is the prototype of CO-poor galaxies. The CO emission appears confined only to the HII regions in the spiral arms, and the central region seems devoid of molecular gas. This lack of CO emission is even more surprising if we consider that, in general, interacting galaxies, like M81, has higher CO luminosity than non-interacting galaxies. This non-typical physics of the molecular gas makes M81 an optimum candidate to study the X conversion factor between CO and H$_2$ molecules.

2. Detection and distribution of the molecular gas

Observing with the IRAM 30m telescope the inner ~1.6 kpc of M81, we found that there are both regions completely devoid of molecular gas and regions in which the CO is clearly detected and the signal is strong. In agreement with Brouillet, Baudry, & Combes (1988) and Sakamoto et al. (2001), the central ~300 pc are devoid of CO(1-0) emission, and the more important molecular gas emission is a clump-structure at the distance of around 460 pc from the nucleus in the North-East direction (Fig. 1 left panel).

3. Line ratio and clumping properties

Studying the line intensities, we found very low temperatures both in CO(1-0) and CO(2-1) transitions: for the detections ≥ 2σ the average brightness temperature in CO(1-0) is of 33.44 mK, while in CO(2-1) is of 21.47 mK. The average $R_{21}$ ratio is of 0.68, a quite low and non-typical value for similar galactic nuclei. Usually, the inner kpc of galaxies have, on average, $R_{21}$ ~0.9, and it is expected even higher for interacting/perturbed galaxies (Braine & Combes 1992). In addition, the line ratio typically decreases from galactic nuclei to spiral arms (Garcia-Burillo, Guerin, & Cernicharo 1993). For M81 galaxy the $R_{21}$ line ratio spans in a wide range of values, without a clear radial trend.
The detailed study of the CO(2-1) emission and distribution, shown in Fig. 1 right panel, allowed us to resolve individual molecular structures of diameters of $\sim 250$ pc and masses of $\sim 10^5 M_\odot$. Molecular structures with these dimensions define Giant Molecular Associations (GMAs). The $X = N(H_2)/I_{CO}$ conversion factor computed for all the individual resolved GMAs of M81, assumed virialized, takes a value from $\sim 10$ to $\sim 18$ times larger than the standard Galactic value ($X = 2.3 \times 10^{20}$ mol cm$^{-2}$ (K km s$^{-1}$)$^{-1}$, Strong et al. 1988).

4. Heating of the gas

In M81 center, the molecular gas is absent or sub-thermally excited. This could be due to a flux of cosmic rays and a far-ultraviolet (FUV) surface brightness too low to heat the molecular gas component of the interstellar medium.

5. Conclusions

M81 appears as a galaxy with an unusual physics of the molecular gas in the central region, if compared to galaxies with similar distances and morphological type: the CO is absent or very weak, the $R_{21}$ line ratio is very low, and the $X$ conversion factor is extraordinarily large. We interpret these results as due to a lack of excitation of the gas, more than the absence of molecular gas.

References

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