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Morphological comparison of molecular emission with continuum emission in ALMAGAL clumps

The analysis of the line emission at millimetric wavelengths is a powerful tool for studying the kinematic and thermal conditions of the gas in star-forming regions. However, the question of how well different species trace the emission of dust in the continuum at various scales has been addressed in the literature either by comparing the region of emission of the different lines with the region emitting in the continuum or by using intensity correlators, such as Pearson's coefficient.

In this work, we present an innovative approach to this problem based on the analysis of the correlation between the morphology of the moment-0 maps of lines from eight of the most common molecular species observed in high-mass star-forming regions - namely H2CO, CH3OH, SO, SiO, HCCCN, CH3CN, DCN, and CH3OCHO - and the continuum emission from dust at 1.4 mm on an unprecedented statistically robust sample. The observations are part of the ALMAGAL program, which has observed more than 1000 candidate high-mass star-forming clumps selected from the Herschel Infrared Galactic Plane Survey (Hi-GAL) catalogue (Elia et al. 2017, 2021), with the ALMA interferometer at 1.4 mm. Observed clumps have masses above 500 $M_\odot$, distances up to 7.5 kpc, and cover different evolutionary stages and fragmentation properties.

The morphological analysis we carried out is based on the astroHOG package (Soler et al. 2019), developed to compare the morphology of astrophysical images, or cubes, using the method of the histogram of oriented gradients (HOG). The HOG method is a machine vision tool that uses the intensity gradient orientation to characterise the similarities between two images and evaluates whether the relative gradients in the two images are randomly oriented or preferentially parallel (i.e. the distribution of the angles between the direction of the two gradients peaks around 0°), implying that the morphology of the two images is similar.

Across the sample of the 1013 ALMAGAL clumps analysed, only the emission of H2CO, CH3OH, and SO transitions significantly overlap with the continuum extended emission. Still, the astroHOG comparison reveals that the morphology is poorly correlated. We also run astroHOG over a masked portion of the continuum emission that corresponds only to the densest regions. In this case, we found that the analysed species can be divided into two groups. CH3CN, DCN, HCCCN, and CH3OCHO show a good correlation, while for H2CO, CH3OH, SO, and SiO, the emission mostly does not follow the morphology of the compact part of the continuum. Analysing the ALMAGAL data with the astroHOG method and Pearson's coefficient, the most widespread tool used for comparing the emission of different tracers in the literature, the former gives more accurate and reliable results.

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