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Detection of complex organic molecules in the low-metallicity Large Magellanic Cloud

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Abstract. Using the Atacama Large Millimeter/submillimeter Array (ALMA) 1.3 mm observations, we detected complex organic molecules (COMs) dimethyl ether (CH_3OCH_3) and methyl formate ($HCOOCH_3$), together with their likely parent species methanol (CH_3OH), in two locations identified as 'hot cores' in the star-forming region N 113 in the Large Magellanic Cloud (LMC). This was the first time interstellar COMs containing more than six atoms were detected in a low-metallicity environment, and the first detection of extragalactic CH_3OCH_3 and $HCOOCH_3$. The fractional abundances of COMs in N 113 scaled by a factor of 2.5 to account for the lower metallicity in the LMC are within the range observed in Galactic hot cores. Our discovery has important implications for astrobiology.

Key words. Magellanic Clouds – Galaxies: star formation – Stars: protostars

1. Introduction

Observations of COMs (≥6 atoms including carbon; Herbst & van Dishoeck 2009) in a low metallicity environment with different physicochemical processes than in the solar neighborhood can provide crucial information to address important questions about the origin of

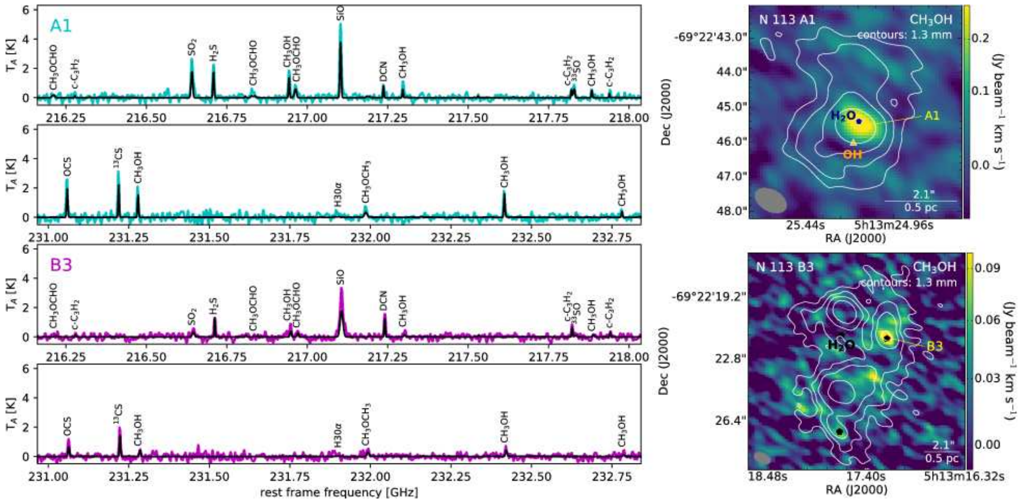

Fig. 1. *Left:* Source averaged spectra for A1 (*top two panels*) and B3 (*bottom panels*) hot cores for two ALMA spectral windows (Sewiło et al. 2018). The synthetic spectra are shown as black solid lines. *Right panel:* Integrated intensity images for CH_3OH (all transitions in the 216.9 GHz spectral window) for A1 (*top*) and B3 (*bottom*). The H_2O and OH masers are indicated. The white contours correspond to the 1.3 mm continuum emission with contour levels of (5, 10, 20, 50) × the image rms noise level of 0.1 mJy beam^{-1}.

COMS and the role they play in pre-biotic chemistry. The nearest laboratory for detailed studies of star formation under metal poor conditions is the LMC (Z_{LMC}~0.3-0.5 $Z_{\odot}$; Russell & Dopita 1992).

N 113 is a prominent star-forming region in the LMC harboring a multitude of massive star formation tracers (massive young stellar objects, interstellar OH and H_2O masers, and compact H II regions) and is associated with one of the most massive LMC CO molecular clouds. COMs were detected toward two 1.3 mm continuum sources we dubbed A1 and B3.

2. Results and conclusions

The local thermodynamic equilibrium (LTE) analysis of six CH_3OH transitions resulted in rotational temperatures of $T_{rot} \sim 130$ K and total column densities of $N_{rot} \sim 10^{16}$ cm^{-2} for A1 and B3. The physical and chemical properties of A1/B3 (e.g., sizes, H_2 number and column densities, association with masers and COMs) are consistent with classic 'hot cores' observed in the Galaxy. A1 and B3 are the only known extragalactic sources showing hot core chemistry with COMs. The (CH_3OH, CH_3OCH_3, $HCOOCH_3$) fractional abundances with respect to H_2 are $(20\pm3, 2.2\pm0.7, 1.4\pm0.4)\times10^{-9}$ for A1 and $(9.1\pm1.7, 1.7\pm0.7, < 0.5)\times10^{-9}$ for B3 – when scaled by a factor of 2.5 to account for the lower metallicity in the LMC, they are comparable to those found at the lower end of the range in Galactic hot cores. This result was surprising since previous observations and theoretical models indicated that the formation efficiency of COMs in the LMC is very low (e.g., Acharyya & Herbst 2015). The metallicity of the LMC is similar to massive galaxy disks at redshift z~1.5, thus the presence of COMs in the LMC indicates that a similar prebiotic chemistry leading to the emergence of life, as it happened on Earth, is possible in the earlier Universe.

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