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High-resolution observations of CH_3CN in the hot corino of NGC1333-IRAS4A

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Abstract. The formation and evolution of complex organic molecules in the early stages of solar-type protostars (Class 0 objects) is crucial as it sets the stage for the content in pre-biotic molecules of the subsequent proto-planetary nebula. In order to understand the chemistry of these Class 0 objects, it is necessary to perform interferometric observations which allow us to resolve the hot corino, that is the warm, dense inner region of the envelope of a Class 0 object, where the complex organic molecules are located. Such observations exist for only two objects so far, IRAS16293-2422 and NGC1333-IRAS2A and we present here Plateau de Bure interferometric maps of a third hot corino, NGC1333-IRAS4A, which show emission of the complex organic molecule CH_3CN arising from a region of size $\sim 0.8''/175$ AU, that is, of the order of the size of the Solar System. Combining these high-angular resolution maps with prior single-dish observations of the same transitions of CH_3CN indicates that extended emission is also present, and we investigate the implications for organic chemistry in hot corinos.

Keywords. Stars: formation, stars: individual (NGC1333-IRAS4A), ISM: abundances, ISM: molecules

1. Introduction

One of the most fascinating questions which remains almost entirely open in Astrophysics is the chemical complexity reached during the birth of stars like our own Sun, and its impact on the later stages, when a planetary system forms. Complex organic molecules have been found in the innermost regions of the envelopes surrounding solar-type protostars, in the so-called hot corinos (Cazaux *et al.* 2003, Bottinelli *et al.* 2004a, b, Bottinelli *et al.* 2007). Both gas-phase and grain-surface reactions have been proposed as formation mechanisms of the complex organics and determining the location of the emission of these molecules can help constraining their formation path. In this context, we present here new interferometric, sub-arcsecond, observations of CH_3CN in NGC1333-IRAS4A (hereafter IRAS4A).

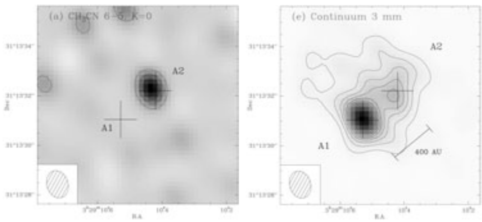

Figure 1. PdB maps of IRAS4A. — **(a)** CH_3CN $J = 6-5, K = 0$ line map with 2σ contour levels of 16 mJy; **(e)** 3 mm continuum emission in IRAS4A. The rms and contour levels are 1 and 10 mJy beam^{-1} respectively. — Crosses show the positions for A1 and A2. The beam size shown in the lower left corner is $1\overset{''}{.}1 \times 0\overset{''}{.}8$. (Adapted from Bottinelli *et al.* 2008)

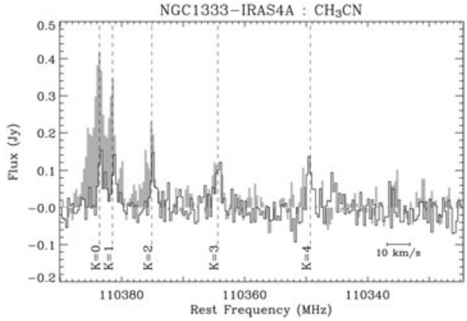

Figure 2. CH_3CN spectra towards IRAS4A. — Shaded = spectrum obtained at the IRAM 30m Bottinelli *et al.* 2004; white = Plateau de Bure spectrum averaged over the emission region of IRAS4A2. Dashed lines indicate the frequencies of the CH_3CN transitions. (From Bottinelli *et al.* 2008)

2. Observations and implications

Observations. IRAS4A was observed with the IRAM Plateau de Bure Interferometer in its most extended (A) configuration. 3 mm and 1.3 mm continuum emission, and five CH_3CN transitions at 110.4 GHz were obtained simultaneously. The reader is referred to Bottinelli *et al.* (2008) for details of the data calibration and reduction. Figure 1-a shows the integrated line emission of CH_3CN averaged over the CH_3CN $J = 6-5, K = 0$ transition while the continuum at 3 mm is displayed in Figure 1e [see Bottinelli *et al.* (2008) for the $K = 1-3$ and 1.3 mm maps]. The line emission maps are unprecedented and show that only the north-west region (A2), the weakest component in the continuum, possesses CH_3CN emission. The spectrum averaged over A2 is compared to the spectrum obtained at the IRAM-30m (Figure 2), and shows that at least 50% (taking into account optical depth effects) of the emission from the low-energy lines ($K = 0, 1$) is filtered out by the PdB, indicating extended emission.

Implications. Using the density structure derived by Jørgensen *et al.* (2002), we can show that the CH_3CN abundance in the cold, outer regions is $\sim 2 \times 10^{-11}$, and that it jumps by about a factor 120 inside a radius of (85 ± 20) AU. From the temperature structure of Jørgensen *et al.* (2002), we deduce that the sublimation temperature of CH_3CN (where the abundance jump occurs) should be in the range 60 to 90 K, in agreement with laboratory experiments. This supports the hypothesis that CH_3CN is formed in the gas phase during the prestellar phase, and freezes out onto the grain mantles in the colder parts of the envelope.When the temperature reaches the CH_3CN sublimation temperature, those ices sublimate, injecting this molecule in the gas phase, which is equivalent to the presence of a hot corino, as seen in the IRAS4A data presented here.

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