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Nitrogen fractionation in high-mass star forming cores and its Galactic trend

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Abstract. The $^{14}N/^{15}N$ ratio is well measured in the terrestrial atmosphere (TA) (~272), and for the pre-Solar nebula (PSN) (~441). Some pristine Solar System materials, like comets and carbonaceous chondrites, are enriched in ^{15}N with respect to the PSN value. Nowadays it is not clear if, and how, these enrichments are linked to the past chemical history, due to the limited number of measurements in dense star-forming regions. In this work, we show the main results of IRAM-30m observations of the J=1-0 rotational transition of the molecules HCN and HNC, and their ^{15}N-bearing counterparts, towards about 90 high-mass star-forming dense cores. We have derived that the $^{14}N/^{15}N$ ratios are concentrated in the range ~ 250-800. Thanks to the very large sample we have also searched for a Galactocentric trend.

Key words. ISM: High-mass star formation – N-fractionation

1. Introduction

Nitrogen, the fifth most abundant element in the universe, exists in the form of two stable isotopes: ^{14}N, the main one, and the less abundant ^{15}N. Molecules found in comets and other pristine Solar system bodies are enriched in ^{15}N, because they show a lower $^{14}N/^{15}N$ ratio with respect to the value representative of the PSN (~441, Marty et al. 2010), but the reasons of this enrichment cannot be explained by current chemical models. Also, the models are poorly constrained by the few observations obtained so far. Because our Sun was born in a rich cluster, possibly including massive stars (e.g Adams 2010), observations of massive, dense star forming cores in different evolutionary stages are needed. We have observed $HN^{13}C$, $H^{13}CN$, $HC^{15}N$, $H^{15}NC$ (J=1-0) with the IRAM-30m Telescope toward a sample of high-mass star forming cores. 27 of these sources belong to the three main evolutionary categories of the high-mass star formation process: 11 high-mass starless cores (HMSCs), 9 high-mass protostellar objects (HMPOs) and 7 ultracompact HII regions (UCHII) (Colzi et al. 2017a, submitted to A&A). This sample has been recently increased with 66 massive dense cores of the survey by Sánchez-Monge et al. (in

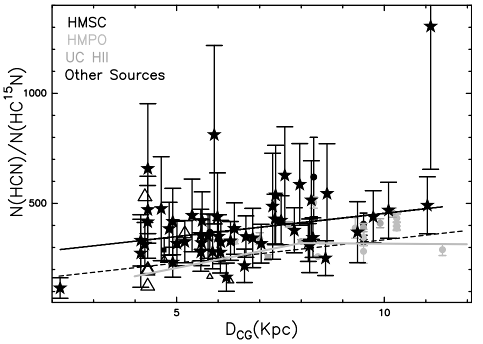

Fig. 2. $^{14}N/^{15}N$ ratios for HCN as a function of the Galactocentric distance of the sources. Same symbols as in Fig. 1 are used. The black solid line is the linear fit, and the grey solid line is the result of the model made by Romano et al. (2017). The dashed line is the gradient found by iAdande & Ziurys (2012). The resulting gradient for HNC is described in Sect. 2.

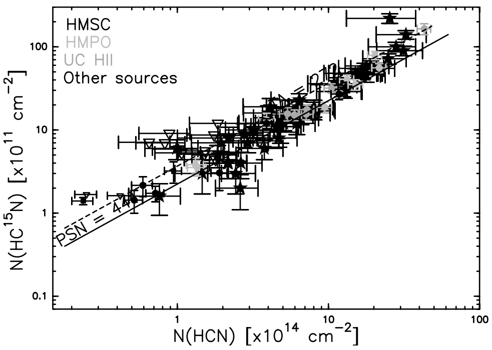

Fig. 1. Column density of the main isotopologue against that of the ^{15}N-bearing one in HCN. The filled points represent the detected sources (black circle=HMSCs; grey=HMPOs; dark grey=UCHIIs, black stars=other sources). The open triangles are the upper limits on column densities. The solid line indicate the values of the PSN and the dashed line that of TA. Note that for HNC we have found consistent results with those obtained for HCN (Colzi et al. 2017b, in prep).

prep.), which however, do not have an evolutionary classification yet.

2. Results

The isotopic ratios $^{14}N/^{15}N$ obtained from HCN are in the range ~250-800 (see Fig. 1) and those from HNC are in the range ~250-550: they are distributed well around the PSN value. These findings are consistent with what was found by Colzi et al. (2017a) and indicate that the extreme low values of the $^{14}N/^{15}N$ (~50, Bonal et al. 2009), measured in some Solar System bodies, cannot be produced in these regions.

Moreover we have plotted the $^{14}N/^{15}N$ isotopic ratios as a function of the Galactocentric distance (see Fig.2). A linear fit to the data provides:

$$\mathrm{HCN/HC^{15}N} = 21.1(8.4)\mathrm{kpc}^{-1} \times \mathrm{D_{GC}} + 244.1(63.2)$$

$$\mathrm{HCN/HC^{15}N} = 18.6(5.5)\mathrm{kpc}^{-1} \times \mathrm{D_{GC}} + 225.3(41.1)$$

The small trend that we found at small distances (2-8 kpc) is consistent with the nucleosynthesis and chemical evolution model made by Romano et al. (2017), and with the rich star formation activity near the Galactic center. The model predicts a change in slope between 7 and 10 kpc which is not found in our observations (see Fig. 2).

3. Conclusions

We have found values of the $^{14}N/^{15}N$ ratio that are distributed well around that of the PSN (~441) with a lower limit that correspond to that of the TA (~272, Marty et al. 2009). This study shows also that the isotopic ratio does not vary with time, which, therefore, does not seem to play a role in the fractionation of nitrogen. Thanks to the fact that these sources span a wide range of distances from the Galactic center, we have also found a Galactocentric gradient (Colzi et al. 2017b, in prep). This is the first $^{14}N/^{15}N$ gradient measured in the Milky Way with a very robust statistics.

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